January 2008

SPECIAL ISSUE

Astronomy®

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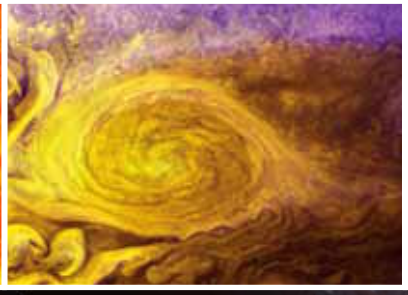
TOP 10 STORIES 2007



THE YEAR'S HOTTEST STORIES!

From testing Einstein's relativity, to brilliant Comet McNaught, an earthlike exoplanet, the first 3-D dark-matter map, and more. p. 28

The colliding Antennae galaxies gleam with new stars. But don't expect fireworks when the Andromeda Galaxy crashes into us.

PLUS:

Jupiter's 5 deepest mysteries p. 38
Earth's impact craters mapped p. 60
Observe celestial odd couples p. 64

BONUS! 2008 night-sky guide pullout inside

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2007
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PLUS:
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Observe celestial odd couples p. 64
BONUS! 2008 night-sky guide pullout inside
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MAIN IMAGE: NASA/ESA/STScI; INSETS FROM LEFT: ESA/C. CARREAU, JHUAPL/SwRI, ESA/HUBBLE, DAVE CURTIS

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60 Earth impacts at a glance

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Astronomy

The world's best-selling astronomy magazine

VOL. 36, NO. 1

january 2008

NASA/JPL/SSI

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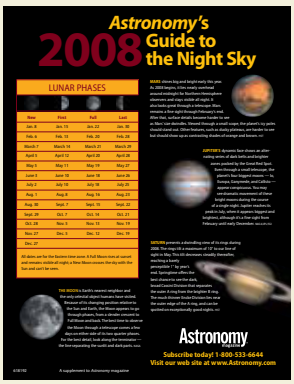
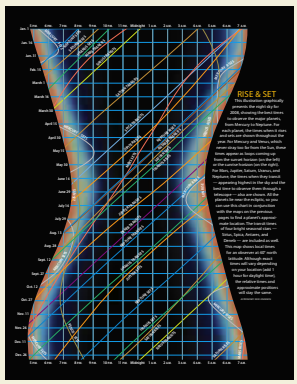
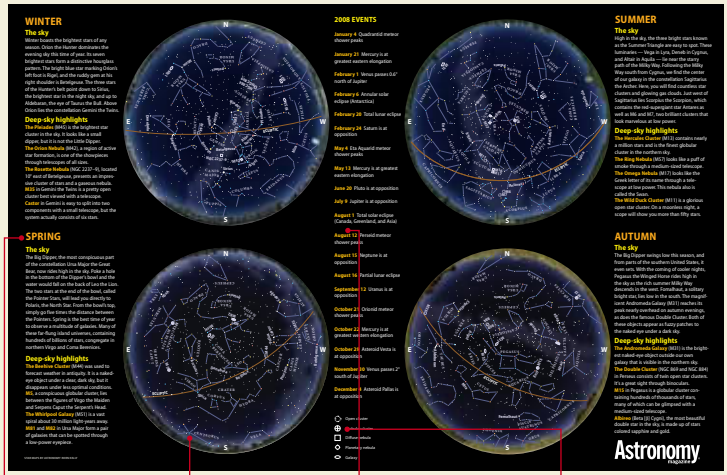
BONUS PULLOUT!

Astronomy's sky guide will keep you looking up all year.







Get Moon phases for 2008, planet rise and set times, and info on which planets to watch this year.

Each season offers its own observing treats to explore.

Star maps show you the entire sky.

The calendar lists the year's must-see sky events.

Find deep-sky objects easily with this map key.

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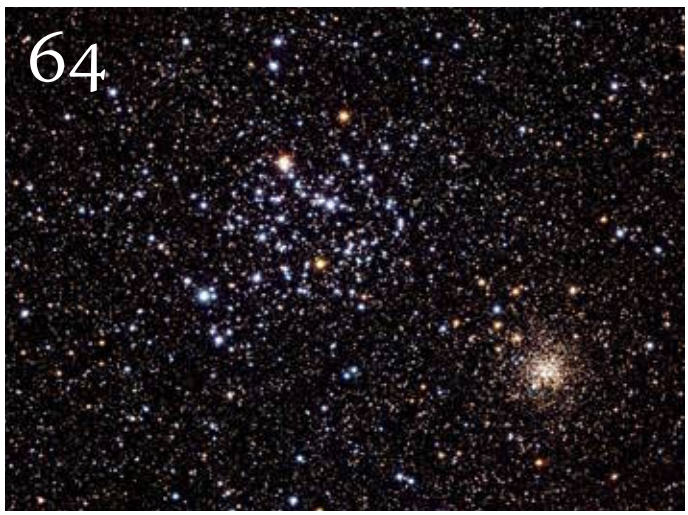

BERNHARD HUBL

CHARLES SHAHAR

BY DAVID J. EICHER

Happy birthday, *Astronomy* magazine

In August 1973, Wisconsin amateur astronomer Stephen A. Walther published the first issue of *Astronomy* magazine. Humble in its beginnings, the magazine grew in less than 10 years to be the largest-circulation astronomy magazine in the world, a position it still holds.

This year, *Astronomy* celebrates its 35th anniversary. We do so in style, continuing as the world's leading magazine on our topic and with fantastic plans for great stories and features in the upcoming months. We'll present a new web site that brings you vast amounts of interactive material and many subscriber-only bonuses. Additionally, you'll see a very special anniversary issue later this year.

Keep your eyes on the magazine and on our web site this year, and I think you'll be delighted at what you see.

I'd like to share two happy notes about *Astronomy*'s staff. First, Francis Reddy has been promoted to senior editor. Frank is a talented writer and editor who provides a great deal of vision to the magazine through his planning and execution of features on the science of astronomy, as well as expertise on the hobby.

In 1982, Frank became an assistant editor of *Astronomy*. He moved on in 1985 to work with museums, and a growing interest in information technology took him in still another direction. Events came full circle in 2004, when he returned to the magazine. Frank has played an important role in developing Astronomy.com. During this recent redesign, he led the development of our new online software tools.

His most recent book, *Celestial Delights*, was published in 2002.

Please also help me congratulate Valerie Penton on her promotion to editorial associate. Val is the one who takes care of a mass of details, correspondence, contracts, meetings, and other day-to-day business.

ASTRONOMY: WILLIAM ZUBACK

Senior Editor Francis Reddy (left), and Editorial Associate Valerie Penton

When asked about her interests, one answer comes first. Says Val, "I have a passion for furry critters." Val volunteers at the Elmbrook Humane Society. She also takes one of her cats, Oliver, to a local nursing home to lift the spirits of the patients there. "We get many smiles and hugs," says Val.

Reading good mysteries also occupies some of Val's time. "Pondering the elements and putting them together is a challenge," she says, "and I like challenges." She takes on the challenge of keeping the *Astronomy* office running smoothly and accomplishes that admirably every day.

Congratulations to Frank and Val for their well-deserved promotions.

Yours truly,

David J. Eicher
Editor

Astronomy

Volume 36, Number 1

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Art Director LuAnn Williams Belter

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January web extras

Go beyond the stories printed in this issue with these subscriber-only features. Monthly web extras bring you additional research, interviews, photographs, and animations that our editors turned up while creating the magazine stories.

"Top 10 space stories of 2007" **page 28**
Get the back stories on this year's top 10.

"The biggest planet's 5 deepest mysteries" **page 38**
Hear sounds the Voyager spacecraft recorded as it flew past giant Jupiter.

"Observe celestial odd couples" **page 64**
Challenge yourself to find 10 more unique pairs.

"Eyepiece ABCs" **page 78**
See how optics are configured inside various eyepieces.

"Tour two more clusters in Taurus" **page 80**
Use binoculars to tease out yet another pair of star clusters in the Bull.

This month's top blogs

Editors put their spin on current events in the staff blog. You can share your opinions on news headlines and popular culture, too.

1. **SO LONG, FUSE.** At the veterinarian, they do it with an injection. When astronomers want to "put to sleep" one of their pets, they use a mouse click. **BY DANIEL PENDICK**
2. **BEHIND THE SCENES AT YERKES.** Check out pictures from when *Astronomy* toured this historic observatory. **BY DAVE EICHER**

3. **THOSE MAGNIFICENT ROVING MACHINES.** Carmakers take note: The Mars rovers have surpassed their life expectancy by 13 times. **BY DICK McNALLY**

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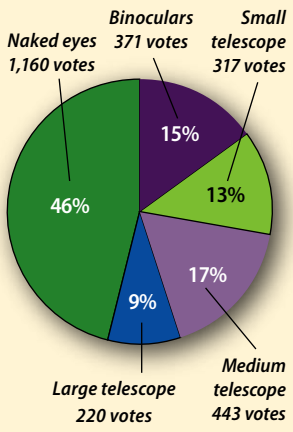
Featured video

HOW TO MAKE YOUR OWN ASTRONOMY LIBRARY
Senior Editor Michael E. Bakich describes types of astronomy books and how to collect them.

Online poll results

Which do you use most to observe the sky?



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Senior Editor Richard Talcott revisits Supernova 1987A 20 years later and explains how it influenced our understanding of exploding stars.

FLY ME TO THE MOON
Author Ed Belbruno talks about low-fuel orbital missions and his book, *Fly Me to the Moon.*

PHOENIX TO HEAD TO THE RED PLANET
Team member Andy Shaner provides insight on NASA's Phoenix mission to Mars.

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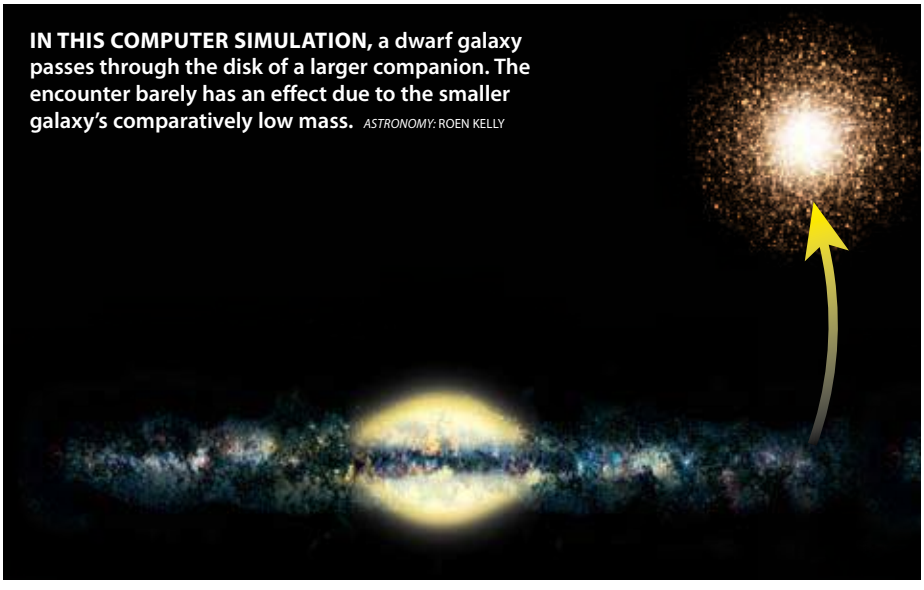
Understanding galactic distortions

In "The ugly side of gravity" (August 2007), something seems to be missing. As the smaller galaxy passes through the larger galaxy's disk, it seems only logical that the gravity of the smaller galaxy would distort the larger galaxy. However, distortion of the plane of the larger galaxy is not even suggested in the accompanying diagrams. Shouldn't it be? — **ROBERT KEELER,** CULVER CITY, CALIFORNIA



IN THIS COMPUTER SIMULATION, a dwarf galaxy passes through the disk of a larger companion. The encounter barely has an effect due to the smaller galaxy's comparatively low mass. *ASTRONOMY:* ROEN KELLY

The disk doesn't respond because I represented it as static and fixed in the simulation. In reality, gravity is mutually attractive, so there should be a response in the larger galaxy's disk to the dwarf.

With an invader as small as the dwarf shown — having a mass of only 0.1 percent of the disk — the response would be small.

If the dwarf were larger — say, 10 percent of the larger galaxy's disk mass — it might warp the disk or kick material out of it. If it were even larger, it could disturb the larger galaxy's disk enough to destroy it. — **KATHRYN JOHNSTON,** ASSOCIATE PROFESSOR OF ASTRONOMY, COLUMBIA UNIVERSITY, NEW YORK

Robert Burnham, Jr., Memorial fund established

I and other admirers of Robert Burnham, Jr. — the astronomer and author of *Burnham's Celestial Handbook* — have established a nonprofit fund for a memorial to him at Lowell Observatory in Flagstaff, Arizona. See rbjm.org for more information or contact me if you are interested in donating: tortega@villagevoice.com. — **TONY ORTEGA,** EDITOR, *THE VILLAGE VOICE,* NEW YORK

Flipped-out Venus

In Bob Berman's "For sale: the equator" (September 2007), he wrongly states, "Venus' equator is highly tilted, which would normally create wild seasons." In fact, Venus has a 177° obliquity, or within 3° of being upside down in relation to the other inner planets. Therefore, it rotates east to west from our earthly perspective. — **FRED WHITAKER,** LITTLETON, COLORADO

As this reader correctly points out, Venus' tilt puts its equator almost back in line. It's like a person standing on his head. He's as flipped as possible, but his belt is almost where it should be. — **BOB BERMAN**

Kudos for Dorminey

I enjoyed reading Bruce Dorminey's "What lurks between galaxies?" (September 2007). It was full of information and well written. Thanks for providing a top-notch magazine with excellent content. — **NATALIE WILLIAMS,** ROSEVILLE, CALIFORNIA

Seeing clearly

"Is Lasik for you?" (November 2007) states DioptRX lenses can correct only astigmatism, not near- or farsightedness. That's misleading, because simply focusing your telescope automatically corrects for near- or farsightedness. So DioptRX plus focusing does it all, better than eyeglasses. — **AL NAGLER,** ROCKLAND COUNTY, NEW YORK

The statement in the article does seem to imply DioptRX lenses are lacking in some way. However, as you point out, most users can "dial out" their eyeglass prescriptions with the telescope focuser. — **DANIEL PENDICK, ASSOCIATE EDITOR**

We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

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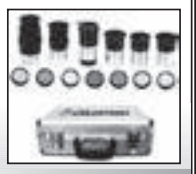

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BY BOB BERMAN

Twelve months of strangeness

We can't argue with British geneticist

John Haldane: "The universe is not only stranger than we suppose, it's stranger than we can suppose." Let's balance out 2008's all-even numerals, which won't repeat for a while, by selecting an odd event in each month of this New Year.

The party starts **January 1**, when Mars shines at its brightest until 2016, while also standing higher in the sky than at any time in the last 48 years. We're now regularly pounding it with spacecraft, but everyone wants to know just one thing: Is there life below the surface? For most of us, the Red Planet has been reduced to that single issue.

On **February 20**, a total lunar eclipse smiles upon our entire hemisphere. The umbral fun begins at 8:43 P.M. EST, with totality starting at 10 P.M. sharp. Watch our nearest neighbor move nearly its own diameter each hour as it enters and exits Earth's shadow. See whether the 51-minute totality looks a normal orange or assumes a rarer black, gray, or white hue.

March is a great month for watching Saturn, which came to opposition at the end of February and is now clear of horizon garbage at nightfall. The glorious rings — twice as reflective as Saturn's body — now angle closer to edgewise, so we see the dimmest Saturn since the century began. As for its strange moon Enceladus, which spews ice into space like a runaway refrigerator icemaker, these "Cold Faithful" geysers are no longer believed to originate from underground liquid water.

April 1 is when Uranus is finally expected to get cell-phone service and provide call waiting to the newly discovered monkey-people on its moon Puck.

May 6 gives us the year's easiest no-brainer peek at Mercury, when that tiny, dense, ruddy, metallic world meets the crescent Moon in fading evening twilight. This is a cool thing. Women love guys who stand outdoors staring at Mercury after they've taken out the garbage.

The solstice lands **June 20** at 7:59 P.M. EDT, which is 1 minute to midnight UT. Here's what's wacky: It's the earliest summer in 116 years! The solstice hasn't happened on the 20th, Greenwich time, since 1892. Is this due to global warming? Rap music? No, it was Pope Gregory. Long story.

A SPOOKY CRESCENT

Moon accompanies October's Halloween revelry.

In **July**, the spotlight shines on Jupiter. It dominates the summer sky at magnitude –2.7, with its closest approach to Earth on the 10th. When you see Jove, try to visualize its enormous magnetic field, bigger in our sky than the Moon, trapping radiation that would make a nuclear-reactor core seem like a hippie tofu love-in by comparison. Within that shield orbits Europa, whose oceans may harbor aquatic life, or, less likely, a water-slide theme park.

August 1 brings a total solar eclipse, visible to those who get off their commuter train at the Mongolia station. If you sit this one out, consolation arrives on the 11th and 12th, when the year's finest meteors emanate from Perseus — especially after the Moon sets at 1:30 A.M.

If you happen to be in Brazil after sunset **September 1**, that's where an unobstructed horizon will catch the gorgeous meeting of Venus, Mercury, Mars, and the Moon. People dodging fire ants from Florida's gatored communities will see it as well. In northern states, it'll be too low.

In **October**, a spooky thin crescent Moon accompanies Halloween's revelry. The sky object most associated with this bizarre tradition is the Pleiades star cluster, oddly linked with All Hallows' Eve (Halloween) and devilry for more than 1,000 years. Through binoculars, it's a treat.

In **November**, give thanks on Thanksgiving that the Sun cannot ever "go supernova," that your paranoid neighbor hasn't yet installed a 200-million-candlepower yard light, and that only Venus and Uranus are shrouded in boring featureless clouds.

December 1 brings the year's best conjunction, forming a triangle reminiscent of the nightmare that was 5th-grade geometry. A quick oddity from each trio member: Venus is tipped almost perfectly upside down. Jupiter spins faster than any celestial object between Cleveland and the Dog Star. The Moon's surface is as dark as asphalt.

Bonus strangeness: the exceptional Full Moon of **December 12**. It occurs a mere 5 hours after the closest lunar approach in 15 years, and — as if that isn't enough — it hovers higher in the sky than any Full Moon until 2023. Whoa. Expect fantastic tides and strange behavior from your dog. If he looks at you and barks "Ruth!" it means the Moon reminds him of a baseball.

Haldane had it nailed.

Ethos (e'thos) n. 1. the fundamental character or spirit of a culture. 2. the quality of a work of art that produces a high moral impression, noble and universal. — Webster College Dictionary
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BY STEPHEN JAMES O'MEARA

A Crystal Palace

Last month, I introduced you to some common sky phenomena in the Crystal Palace — a visual array of colorful arcs and rings created when sunlight interacts with ice crystals in high-level clouds. This month, through sheer serendipity, I will share with you a puzzling observation of some uncommon wonders in this mystical palace of sunfire and ice.

Around noon on July 22, 2007, amateur astronomers Edgar Castro (president of the Guatemalan Association of Astronomy), R. Scott Ireland (Plantation, Florida), and I saw a beautiful 22° halo over a churchyard near Antigua, Guatemala.

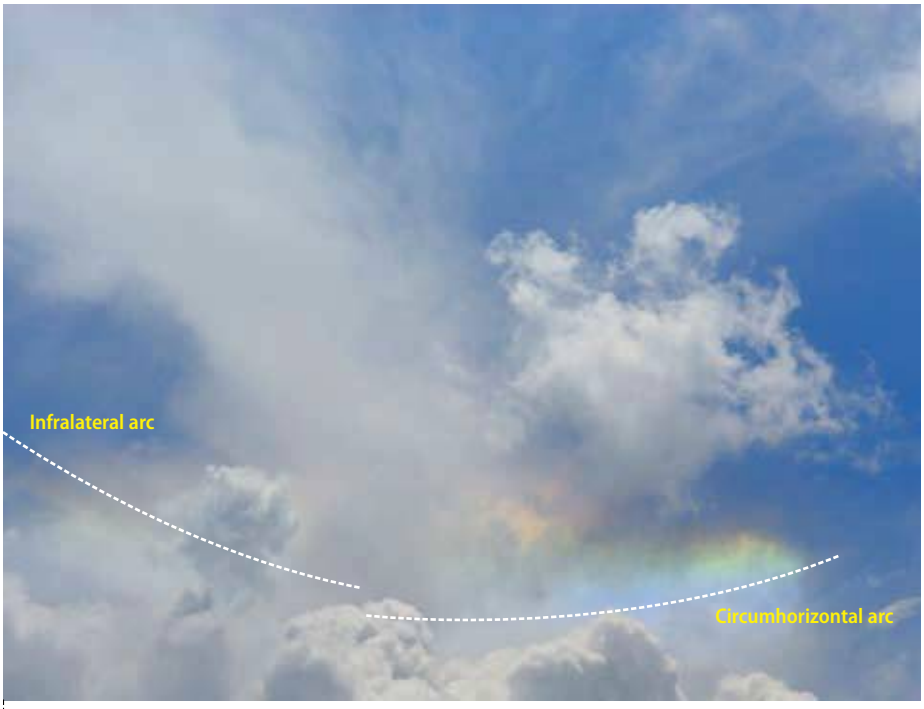
As I described in last month's column, this glowing ring of light occurs when sunlight passes through opposing sides of pencil-shaped (hexagonal) ice crystals oriented randomly in all possible directions.

That day, however, another halo — to the lower left of the Sun, much fainter and wider — attended the 22° halo. It had a 46° radius (two fully outstretched hands held at arm's length) and appeared as a long, dim arc of orange light just above the head of a swelling cumulus cloud.

There is a 46° halo. And, like our orange arc, it most often takes the form of a segment. Formation of a complete 46° halo is extremely rare. To create it, more than 90° of sky centered on the Sun must be glazed with randomly oriented, perfectly formed, hexagon-shaped ice crystals. In addition, sunlight must either enter the side of a pencil crystal and exit through its basal face, or pass through the vertical face of a plate crystal and exit through its side.

Either way, the crystals act like 90° prisms, allowing sunlight to pass through only a narrow range of angles, the minimum of which is 46°.

The 46° halo is always fainter than the 22° halo because some of its light is lost by reflection during transmission. The light we see is also spread across a much greater area of sky, making the halo less visible to the eye. Like the 22° halo, the 46° halo has an orange inner edge that gradually fades to blue. But owing to the halo's larger angular extent, only the warm part of the spectrum is obvious to the eye.



PARTIAL INFRALATERAL AND CIRCUMHORIZONTAL ARCS are barely visible in this photograph. Both form as sunlight refracts through ice crystals of varying shapes. SCOTT IRELAND

Vanishing act

After an hour of casual gazing, the 46° halo segment vanished and the 22° halo faded. Then something strange happened. A bright arc — much brighter than the 22° halo — suddenly appeared in the region of the 46° halo directly below the Sun; it had a luminous orange inner edge and a diffuse pastel blue rim with a full spectrum of colors in between.

Even more spectacular, yet another halo segment appeared tangential to, and to the lower right of, the new arc. It shone vibrantly with an iridescent blue-green color, like peacock feathers under the light of a low Sun. Careful inspection revealed the halo segment also had thin yellow and orange bands fringing its inner edge. While the order of the colors was the same in the two new halo segments, their relative intensities were reversed.

We were perplexed. How could the 46° halo be brighter than the 22° halo? How could its color be so vivid? And what was the curious iridescent band kissing it to the lower right?

Clearing the confusion

The solution to this puzzle is the Sun's altitude. We observed the new arcs from 1:18 P.M. until 1:30 P.M. local time, before low clouds covered the display. During that time, the Sun's elevation dipped from 72° to 70°. The timing was uncanny. When the Sun is between 63° and 75° above the horizon, a rare halo arc, known as the infralateral arc, can appear superimposed on the 46° halo and be mistaken for it.

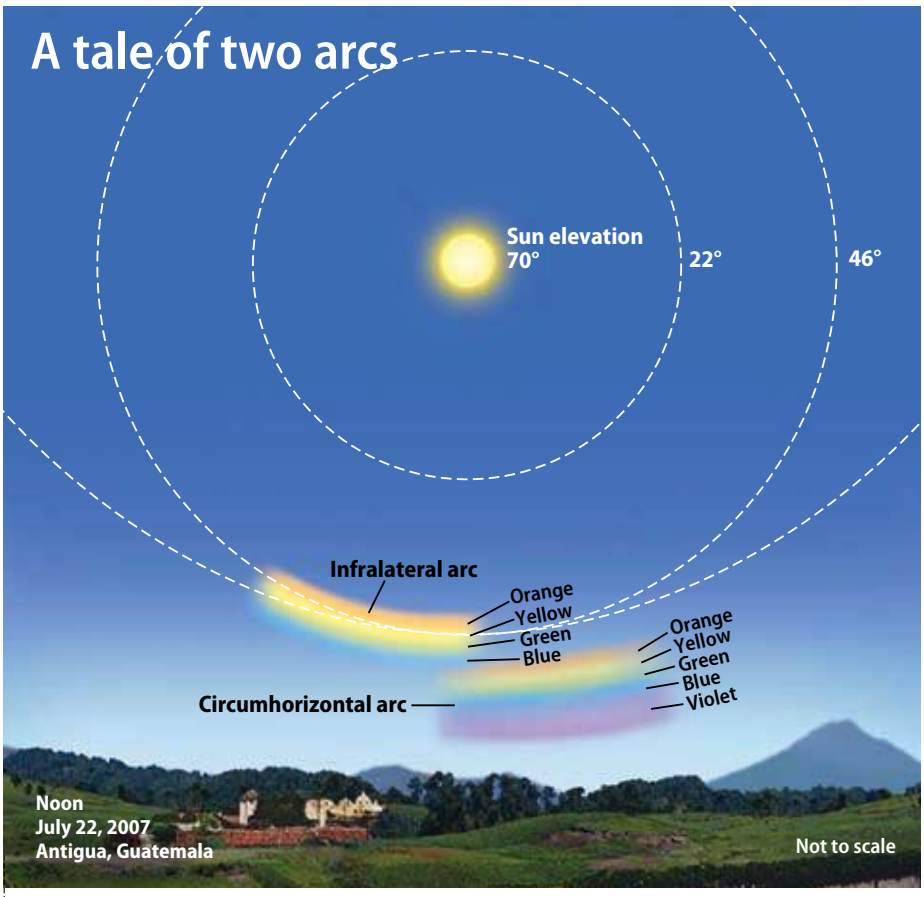
The difference between the two phenomena is clear: The infralateral arc is brighter than the 46° halo, so it can appear in the sky when the 46° halo is absent. The infralateral arc can also display a full range of spectral colors that are obvious to the unaided eye.

Like the 46° halo, the infralateral arc forms when sunlight passes between the sides and basal ends of hexagonal pencil crystals — but only at solar elevations greater than 58°. The infralateral arc's appearance varies dramatically with elevation, but again, we had seen it just as it was masquerading as a 46° halo segment that curved upward from the horizon.

What, then, was the brilliant and highly iridescent splash of blue light to the infralateral arc's lower right? It was a segment of yet another uncommon ice-crystal phenomenon known as the circumhorizontal arc. Through yet another optical coincidence, the circumhorizontal arc (which parallels the horizon) touches the 46° halo (or, in this case, the infralateral arc) at only one Sun elevation: 68°.

Just as the infralateral arc is easily confused with the 46° halo, the circumhorizontal arc can be confused with the infralateral arc, especially at solar elevations around 70°. It appears conditions were right for us to see both phenomena simultaneously.

To create the circumhorizontal arc, sunlight must enter the vertical side of a hexagonal plate crystal and exit through its horizontal lower face. The result is an arc of light at a constant elevation. The circumhorizontal arc's full spectrum of colors can be the most intense display in the Crystal Palace. It is rivaled only by its more common counterpart, the circumzenithal arc, which forms when sunlight enters the upper face of a falling plate crystal and exits its side.



A RARE COINCIDENCE of solar elevation and atmospheric conditions simultaneously projected infralateral and circumhorizontal arcs in the Guatemalan sky. *ASTRONOMY:* ROEN KELLY

A rare treat

No one knows for sure how often infralateral and circumhorizontal arcs occur. It may be as seldom as once or twice a year.

One reason for their rarity is that the solar elevation has to be greater than 58° to see them as well-defined arcs below the Sun; from mid-northern latitudes, then, they occur only during the summer months. The arcs can also go unnoticed because they occur at great angular distances from the Sun.

Another problem is that only fragments of the phenomena may blossom into view for a short period of time. Then again, so few people see them because so few people look for them. So be aware and be prepared. I'm interested in reports of any phenomena associated with the Crystal Palace. I'm especially interested in any alternative explanations of the rare halo displays reported here. A

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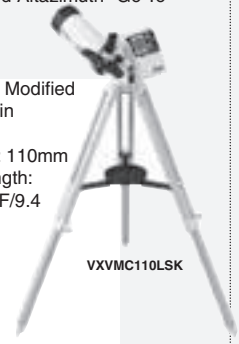

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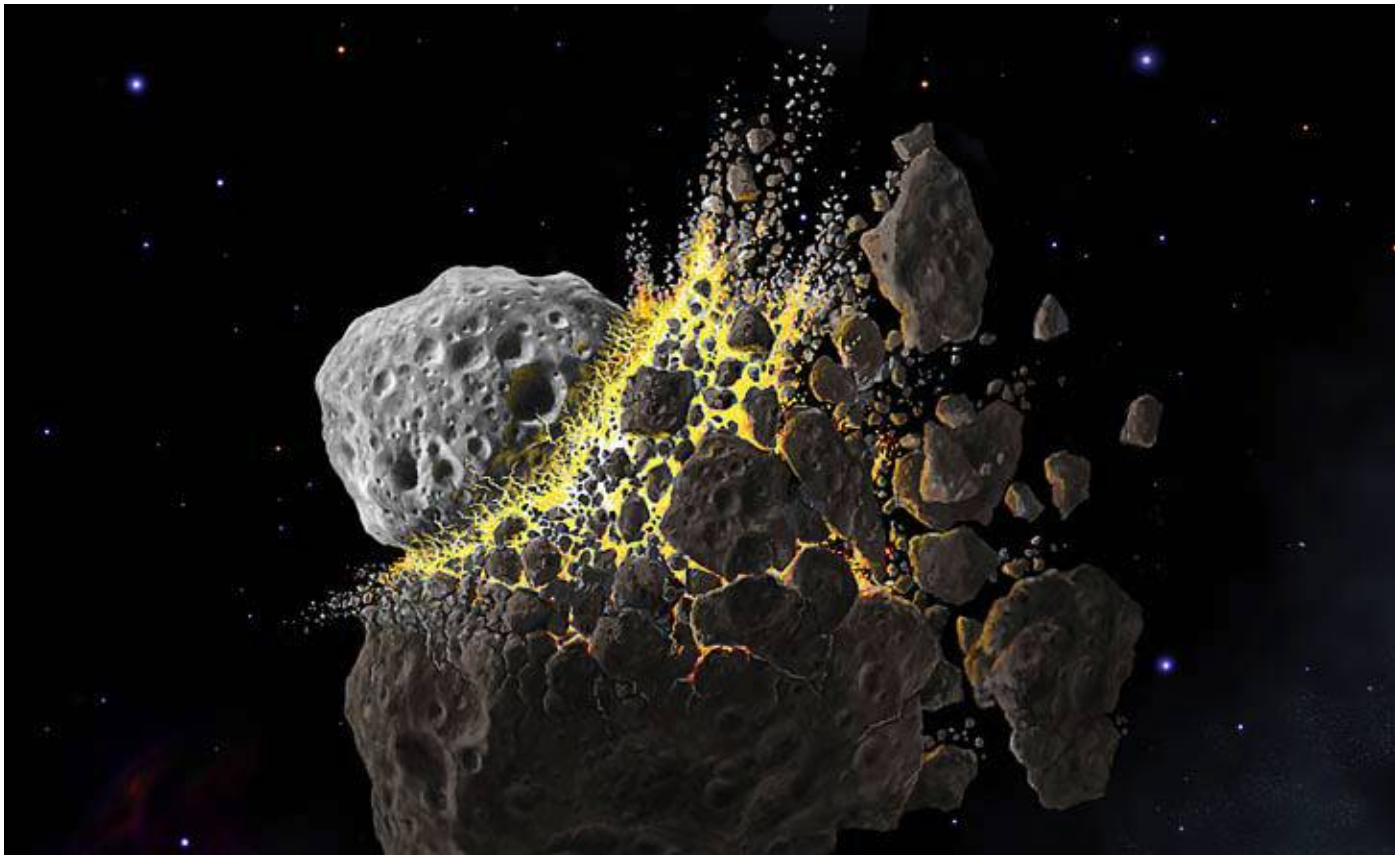
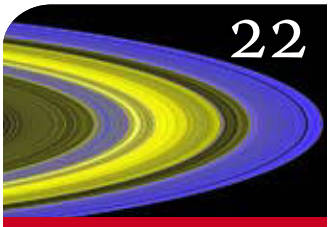


FATEFUL ENCOUNTER. **Computer modeling indicates the collision of two main-belt asteroids, shown in this artist's reconstruction, unleashed thousands of fragments. One 6-mile-wide (10 kilometers) fragment later stuck Earth and condemned the dinosaurs to extinction.** DON DAVIS (SWRI)



24 **Seasons change on Neptune**

25 **Cassini scopes Saturn's two-toned moon**

26 **Distant galaxy gets a weigh-in**

27 **Spitzer witnesses a cosmic ice storm**

Asteroid sleuths find the dino killer

An asteroid smash-up 160 million years ago later contributed to the dinosaurs' extinction, according to findings reported September 6 in *Nature*.

William F. Bottke of the Southwest Research Institute in Boulder, Colorado, and two colleagues used a computer model to determine the source of the 6-mile-wide (10 kilometers) asteroid that struck Earth 65 million years ago. The impact unleashed global changes that ushered the dinosaurs' end.

The computer work suggests a large asteroid, 106 miles wide (170 km), slammed into a smaller body. The asteroid 298 Baptistina is the largest surviving fragment of the collision. It remains in the main belt between Mars and Jupiter. Other members of the Baptistina family of asteroids migrated into the inner solar system, the computer model indicates.

Unfortunately for the dinosaurs, one of the Baptistina fragments may have crossed Earth's path 65 million years ago. The scientists believe a smaller Baptistina fragment struck the Moon 108 million years ago, creating 53-mile-wide (85 km) Tycho Crater. — **DANIEL PENDICK**

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Worth the wait

Japan launched its long-delayed Moon orbiter, Selene, September 14. It will survey the Moon's physical contours and mineral resources.

QUICK TAKES

THE NEW WAVE
Astronomers detected periodic oscillations, called Alfvén waves, in the Sun's outer atmosphere for the first time.

NICE JOB
An industry team led by Boeing Co. will produce the Ares I upper-stage rocket. The Ares I will succeed the space shuttle.

PET PROJECT
Russia's Foton-M bio-satellite successfully landed September 26 in Kazakhstan with live animals from biology studies.

MAUI MEGAPIXELS
Astronomers installed the world's largest digital camera at Maui's Pan-STARRS-1 telescope.

LOVE LIGHT
Biologists discovered that corals possess primitive photoreceptors that synch their reproduction to the Full Moon's light.

THE NEW NuSTAR
NASA restarted the NuSTAR mission after a 2006 funding cutoff. The black-hole-watching satellite is slated for launch in 2011.

SAY CHEESE
IMAX Corporation and Warner Bros. Pictures will record the 2008 Hubble Space Telescope servicing mission for a future film.

CHINA MOON
A Chinese space official said his country will establish a lunar base after 2020.

PLANET SCOPE
Astronomers linked radio telescopes in Australia, China, and Europe to study the galaxy 3C273.

SPACE SICKNESS
NASA funded 17 research projects to assess and reduce radiation risks to astronauts. The risks include radiation poisoning, cancer, and direct tissue damage.

Stars found ripe to make planets

A massive belt of warm dust around a star system 424 light-years distant may have the right ingredients and conditions to form a rocky terrestrial planet, according to new spectroscopic data from the Spitzer Space Telescope.

Senior research scientist Carey Lisse of Johns Hopkins University in Baltimore discussed the new findings October 10 at the 39th annual Division for Planetary Sciences meeting in Orlando, Florida.

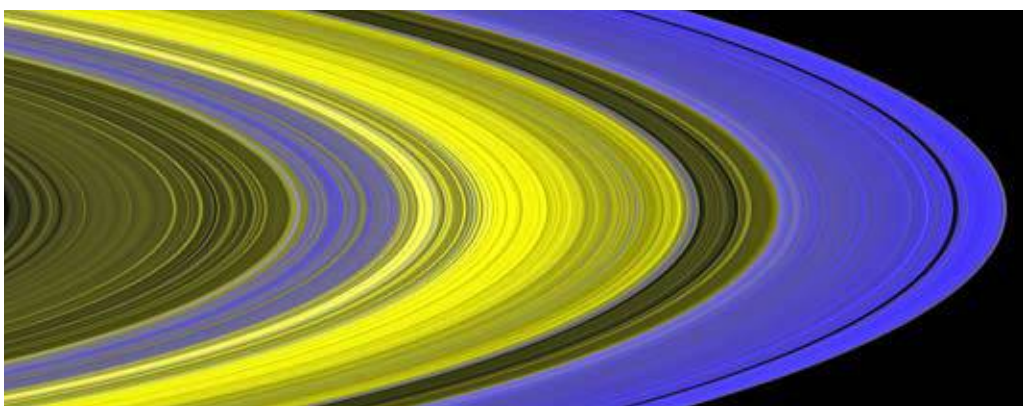
Astronomers have known for years that one of the two stars in the binary system HD113766 sports a dusty ring. The new spectra indicate HD113766's dust belt falls within the star's habitable zone, where water could exist in liquid form. The disk also appears to contain both rocky and metallic materials, the same mixture that formed rocky planets in our solar system.

"What we are seeing is fine particulate dust created by collisions in a primitive asteroid belt undergoing accretion to form a terrestrial planet in its early stages, or the result of a massive collision and disruption of a Ceres-sized object near the end of the planet-building stage," says Lisse.

The dust belt's temperature, location, makeup, and mass suggest the potential to build a Mars-sized planet in 10 to 100 million years. The stars are young enough — 10 to 16 million years old — to still be in the early stages of planet formation. **— LAURA LAYTON**

NASA/JPL-CALTECH/JHUAPL

WARM DUST. A belt of warm dust encircles the Sun-like parent star HD113766A in this artist's concept. The belt may spawn a rocky planet.



NASA/JPL/UNIVERSITY OF COLORADO

STICKY SITUATION. Material in Saturn's massive B ring (yellow in this false-color image) clumps so tightly it's hard to measure its mass. The rings contain 3 times the mass of the saturnian moon Mimas.

Saturn's rings carry extra weight

Saturn's rings may contain a lot more material than astronomers previously thought, says University of Colorado planetary scientist Glen Stewart. He reported this finding October 8 at a meeting of the American Astronomical Society's Division for Planetary Sciences in Orlando, Florida.

Stewart's computer simulations show gravitational attraction causes ring particles to bunch into clusters organized in strands, like a giant spider's web. As the particles orbit Saturn, gravity slowly shears apart some strands while building new ones.

When Cassini observes starlight pass through the rings, it measures the lower-density areas between strands rather than the web material itself. Stewart estimates the densest part of the rings, in the B ring's core, contains more than 3 times the mass previously estimated. This means Saturn's entire ring system holds at least 3 times the mass of its mid-sized moon Mimas. **— RICHARD TALCOTT**

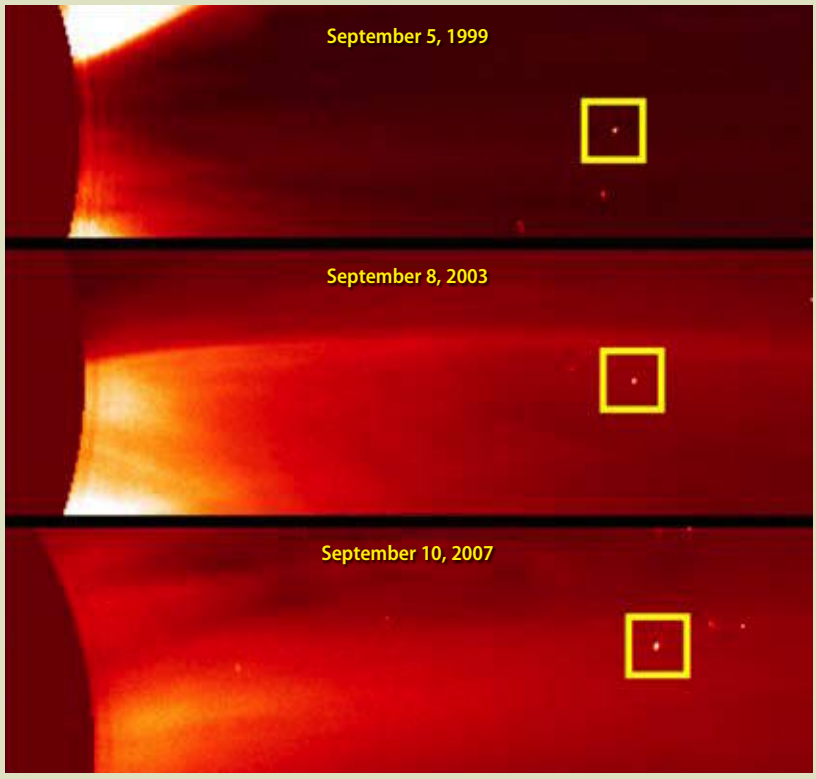
New periodic comet found

The Solar and Heliospheric Observatory (SOHO) satellite spotted a new periodic comet September 11. Although the solar system hosts thousands of comets, fewer than 200 return at regular and predictable intervals, and are thus termed periodic.

SOHO's discovery, Comet P/2007 R5, completes its journey around the Sun in just 4 years. Unlike comets visible from Earth, P/2007 R5 lacks a visible tail or coma.

"It is quite possibly an extinct comet nucleus of some kind," says Karl Battams of the Naval Research Laboratory in Washington. Extinct comets lose their volatile ices, which boil away to form the coma and tail as the body nears the Sun.

German Ph.D. student Sebastian Hoenig first observed the comet in 1999. SOHO confirmed the comet's periodic status when the observatory saw the dirty snowball pass within 4.9 million miles (7.8 million kilometers) of the Sun, just as Hoenig predicted. — **L. L.**



SO PREDICTABLE! The SOHO satellite discovered periodic comet P/2007 R5 (inside yellow boxes). The icy mass loops around the Sun every 4 years. ESA/NASA

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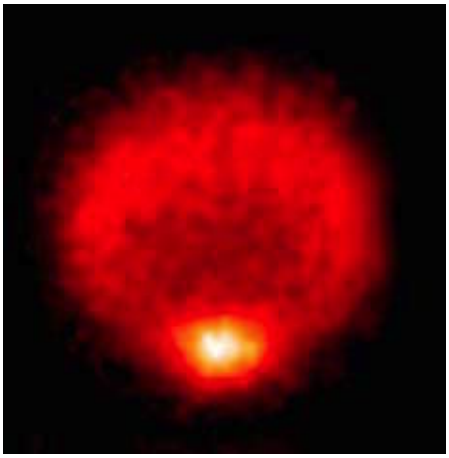


ESO/NASA/JPL-CALTECH

HOT SPOT. Neptune's south pole warms up during summer in its southern hemisphere, just like on Earth. This indicates seasons.

Seasons change on Neptune

Neptune undergoes seasonal climate change. Astronomers determined this by mapping the ice giant's surface temperature with Chile's Very Large Telescope.

Neptune's average temperature plunges as low as –370° F (–223° C). However, Neptune's south pole is about 18° Fahrenheit (10° Celsius) warmer than the rest of the planet, the researchers reported September 18 in *Astronomy and Astrophysics*.

"Neptune's south pole is currently tilted toward the Sun, just as the Earth's south pole is tilted toward the Sun during summer in the southern hemisphere," says NASA's Glenn Orton. Orton, one of the study's authors, works at the Jet Propulsion Laboratory in Pasadena, California.

Summer at Neptune's south pole lasts about 40 Earth years. The planet is about 30 times farther from the Sun than Earth. It receives one-thousandth the amount of sunlight Earth does.

During Neptune's summer, warmer temperatures at the planet's south pole allow methane to escape into its upper atmosphere. Astronomers predict similar seasonal changes will occur during the summer at Neptune's north pole. **— L. L.**

Canada's handy robot

Canada's "special-purpose dexterous manipulator," or Dextre, is more handy than an astronaut but not nearly as smart. The 2,870-pound (1,300 kilograms) robot manipulator will grace the end of the robot arm on the International Space Station (ISS), providing precise manipulation capabilities for external work on the station without risking lives during extended spacewalks.

Scheduled for launch in February 2008, Dextre lost its temporary job assignment to the Hubble Space Telescope repair mission when NASA transferred that task to an astronaut crew. The machine's vaguely humanoid architecture features 2 seven-jointed arms plus "hands." These grapplers do not have fingers per se, but their grippers can hold an array of tools and grab small objects.

The robot resembles an extra from one of the *Terminator* movies. However, its appearance is rendered somewhat comical by the disk-shaped "beanie" atop its torso, which fits into a receptacle at the end of the station's long robot arm.

Each arm, mounted to a shoulder-like joint, consists of a series of positional joints. The joints provide a full range of motion: shoulder roll, yaw, and pitch; elbow pitch; and wrist pitch, yaw, and roll.

The end of each arm includes a sensor to measure exactly how much force the arm exerts on the object of its attention. The sensor allows operators to tighten bolts or tug on levers — just hard enough but not too hard — when working on ISS.

Below the shoulder/torso sit the "hips," which straddle a body-roll joint. On each hip, much like a human handyman, Dextre sports tool caddies, accessible to each arm.

A set of video cameras perches on one of the hips. Below the hips sits a special latching mechanism that allows the robot to work from any of a dozen external work sites. These include a rolling cart that moves along ISS' truss-mounted railway.

Dextre will relieve astronauts of many tasks that now require time-consuming, arduous, and hazardous spacewalks. The range of astronaut labor Dextre can take over is hard to judge, but NASA experts believe it's between a quarter and half.

CANADIAN SPACE AGENCY

LEND A HAND. Canada's contribution to the International Space Station includes Dextre, a dual-armed robot manipulator. It will replace human astronauts on routine, but potentially dangerous, maintenance and inspection chores.

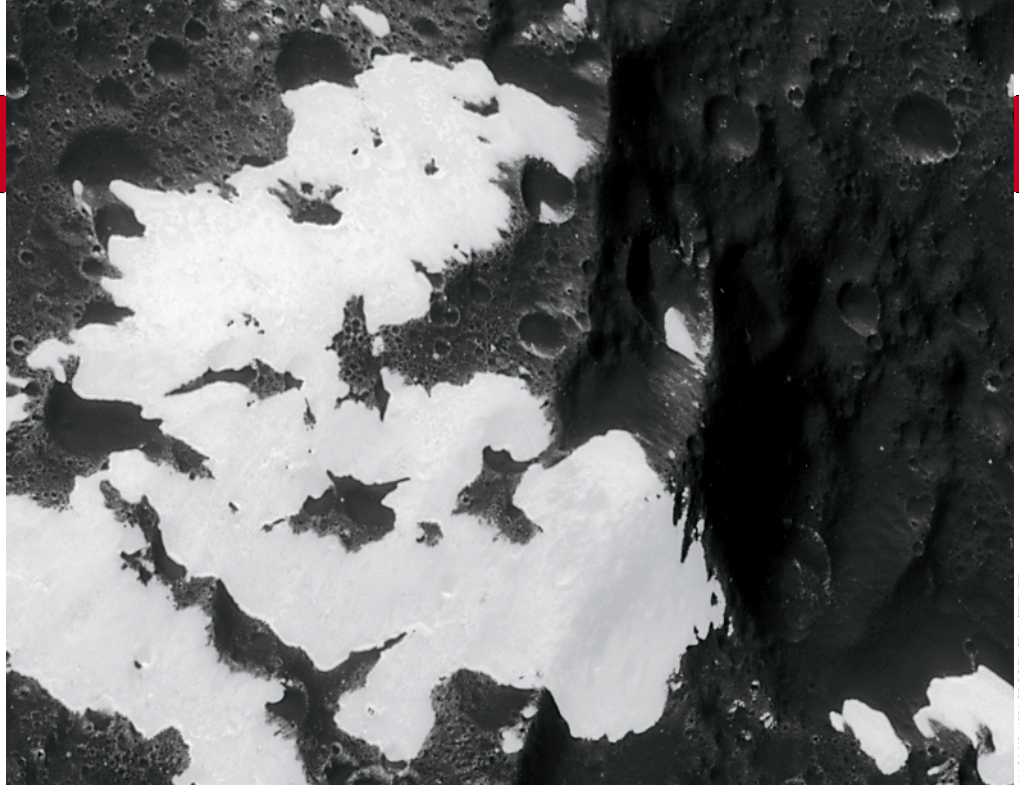
Dextre's tasks will include replacing batteries, attaching and detaching instrument covers, plugging and unplugging cables, placing and retrieving exposure samples, adjusting thermal and debris impact shields, and inspecting the ISS exterior for damage.

Items that need to be sent out from inside the station, or brought back in, can pass through a garbage-can-sized airlock on the Japanese science lab, which is within Dextre's reach when mounted on the end of the manipulator arm.

Dextre will also allow ISS crew to complete tasks in a more timely manner. Spacewalks take a lot of time to prepare for and have a high overhead, so mission planners string together minor inspection and maintenance tasks for each spacewalk. But it can take months until enough work accumulates to justify the risk of leaving the safety of the crew modules. Dextre can be moved into position for work in a matter of days.

Back when NASA thought it was too dangerous for a shuttle crew to perform the final Hubble Space Telescope repair, the agency considered a robotic mission performed by Dextre instead of astronauts. But the needed repairs would have challenged Dextre's skills as well as those of the robot's human controllers: Confirmation of each command could take as long as 2 seconds because of the distances between Hubble, relay satellites, and controllers.

On ISS, though, Dextre will prove the perfect handyman to service the station's operational needs without unnecessary risks to the crew. **— JAMES OBERG**



NASA/JPL/SPACE SCIENCE INSTITUTE

BLACK-AND-WHITE WORLD. **In the transition zone between Iapetus' dark and light hemispheres, ice drapes the slopes of the Voyager Mountains.**

Cassini scopes Saturn's two-toned moon

A close flyby of Saturn's 892-mile-wide (1,436 kilometers) moon Iapetus revealed a two-toned world. One side is snowy white and the other black as tar. The Cassini orbiter cruised past Iapetus September 10 in its continuing exploration of the ringed world and its diverse moons.

The flyby came within 1,020 miles (1,640 km) of Iapetus' surface — 100 times closer than its 2004 visit. Highlights of the tour included a detailed look at the 12-mile-high (20 km) mountain ridge along the moon's equator, which makes Iapetus resemble a giant walnut. — **D. P.**

25 years ago in *Astronomy*

January 1983

Astronomers discovered the true nature of galaxies outside the Milky Way less than 100 years ago. Since then, they have wondered what forces shape such massive quantities of matter.

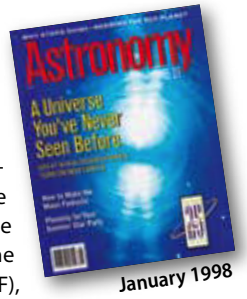
In January 1983, Francis Reddy, now a senior editor of *Astronomy,* explored the origin of galactic structure. His article "To sculpt the galaxies" focused on spirals, which represent about three-quarters of all galaxies in the cosmos.

Reddy explained that "density waves" control a galaxy's overall spiral shape, but local factors such as exploding supernovae and star formation also shape the process. In the end, Reddy concluded, no theory can fully account for all forces responsible for the formation of galaxies.

10 years ago in *Astronomy*

After the successes of the Hubble Space Telescope and the Compton Gamma Ray Observatory, astronomers and stargazers keenly anticipated the launch of the final two of NASA's four planned "great observatories." As *Astronomy* began its 25th anniversary year, astronomer Ray Jayawardhana previewed "NASA's next space observatories" in the January 1998 issue. NASA again demonstrated its aptitude for tongue-twisting acronyms.

The Advanced X-ray Astrophysics Facility (AXAF), now known as the Chandra X-ray Observatory, launched in August 1998 to observe high-energy objects such as supernovae and black holes. The Spitzer Space Telescope, formerly known as the Space Infrared Telescope Facility (SIRTF), has helped astronomers explore the oldest objects in the universe since its 2003 launch. — **ERIN DOLAN**



January 1998

BRIEFCASE

Going the distance

Ten years of work has produced the most accurate catalog of star distances ever, "Hipparcos, the New Reduction of the Raw Data." The catalog contains precise measurements of the distances to nearly 118,000 stars, measured by the European Hipparcos satellite between 1989 and 1993. — **D. P.**

Pulsar push

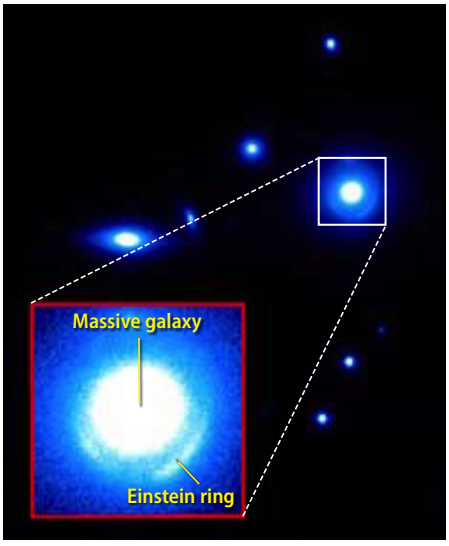
West Virginia high school students and teachers joined astronomers to search for new pulsars using data from the Green Bank Telescope, also located in that state. Called the Pulsar Search Collaboratory, the program received a $892,838 National Science Foundation grant to push ahead. — **L. L.**

Space Age anniversary

To honor the 50th birthday of the Space Age, the International Astronomical Union dubbed asteroid 1982 SH_1 "Astronautica." What's the connection? The space rock is the 100,000th numbered asteroid. And space officially begins at an altitude of 100,000 meters (100 kilometers, or 62 miles), hence the asteroid-anniversary connection. — **D. P.**

Dark reserve

A 2,100-square-mile (5,500 square kilometers) area around Mont-Megantic Observatory near Montreal, Canada, is now officially a dark-sky reserve, according to the International Dark-Sky Association (IDA). The IDA awarded the certification after cities and towns in the reserve adopted laws to limit growth of light pollution and reduce current light pollution by 25 percent. — **L. L.**



P. MARSHALL & T. TREU (UCSB)

PEEK-A-BOO. The gravity of a massive galaxy (central blob) bends light from a distant dwarf galaxy behind it into an "Einstein ring."

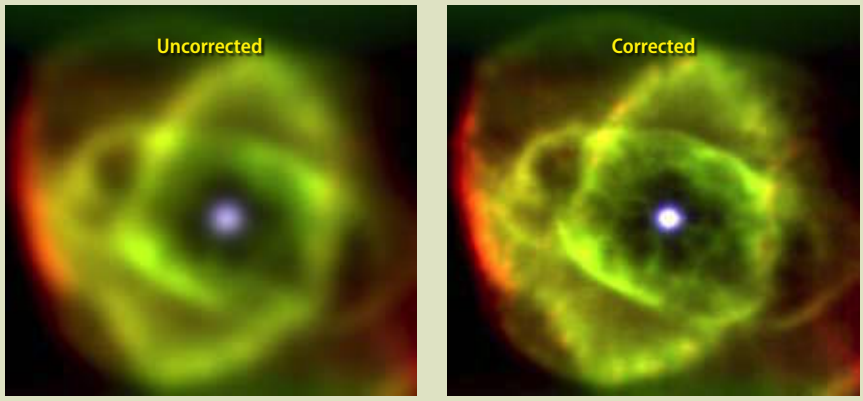
Distant galaxy gets a weigh-in

Astronomers determined the mass of a dwarf galaxy 6 billion light-years distant with the aid of a second galaxy that bent the dwarf's light like a lens, making it visible from Earth.

Philip Marshall of the University of California, Santa Barbara, and his colleagues estimate the distant dwarf contains 1 percent of the Milky Way's mass and is about half the size of most known distant galaxies. The findings are scheduled to appear December 20 in *The Astrophysical Journal.*

The team used the Hubble Space Telescope and the Hawaii-based Keck Telescope to make the observations. From our earthly perspective, the dwarf lies at a great distance behind a more massive galaxy. The larger galaxy distorts the dwarf's light into a bull's-eye pattern called an Einstein ring.

The dwarf appears similar in size and mass to other compact, faint blue galaxies. Moreover, the results confirm that with good observing conditions, ground-based instruments with adaptive optics, like the Keck Telescope, can observe galaxies in gravitational-lens systems just as clearly as the Hubble Space Telescope. **— L. L.**



ALL CLEAR. An upgrade to Palomar Mountain Observatory's adaptive-optics system enabled astronomers to correct atmospheric distortions, creating a sharper image (right) of the Cat's Eye Nebula in visible wavelengths. CALTECH/UNIVERSITY OF CAMBRIDGE

First light for Palomar's new optics

Astronomers at Palomar Mountain Observatory in California produced visible-light images twice as sharp as those of the Hubble Space Telescope with help from new adaptive-optics technology. Until now, such systems worked best in infrared wavelengths, which we can't see directly.

Palomar's existing adaptive-optics system measures atmospheric distortions along the telescope's line of sight and physically deforms a mirror to counteract them. Researchers at the University of Cambridge in England developed the special camera that, when added to Palomar's system, enabled astronomers to snap much sharper images in visible wavelengths.

The Cambridge device, called LuckyCam, acquires the images after correction by Palomar's adaptive optics. In the "lucky imaging" technique, the camera samples 20 times per second or faster. This captures a handful of sharp images at fleeting moments when random fluctuations in the atmosphere create clear seeing conditions. A computer selects the best images and combines them into a single, clearer view. **— D. P.**

New radio telescope opens for business

The first 42 of 350 planned dishes in the Allen Telescope Array (ATA) are now listening to the radio universe. The new facility is located in a dry valley near the town of Hat Creek, California, 290 miles (464 kilometers) northeast of San Francisco.

The array will conduct sweeping radio surveys of diverse astronomical objects. In addition, it will be the first major radio telescope built specifically to search for evidence of extraterrestrial intelligence.

The array is the equivalent of a wide-angle snapshot camera. It can survey radio wavelengths of 21 centimeters spanning 2.45° of sky — 10 times the Moon's diameter — while performing observations for different research projects simultaneously. For example, while conducting a radio survey of a galaxy, the ATA can also listen for signals produced by alien technologies.

Project co-sponsors include the University of California at Berkeley, the SETI Institute, and Microsoft co-founder Paul G. Allen. Allen's foundation has donated some $50 million to the project.

SETI INSTITUTE

LISTEN CAREFULLY. The Allen Telescope Array seeks evidence of alien intelligence.

ATA sponsors tout the effort as a demonstration of how to build a large, powerful radio telescope at an affordable price. The ATA uses mass-produced, 20-foot-wide (6 meters) radio dishes and commercial telecommunications gear.

Project designers explain it is less expensive to use many small dishes than to build a single, large dish. Sophisticated electronics — not to mention miles of wiring — then combine the small-dish signals. **— D. P.**

Round and round

Venus Express completed its 500th Earth day in orbit around Venus September 7. The spacecraft has transmitted more than 1 million million bits (1 Terabit) of data so far.

NASA/JPL-CALTECH/ROBERT L. HURT (SSC-CALTECH)

COSMIC RAIN. **Water vapor permeates an infant solar system 1,000 light-years from Earth, as shown in this artist's concept.**

Spitzer witnesses cosmic ice storm

Astronomers witnessed a cosmic ice storm around an infant solar system for the first time, a team of researchers reported August 30 in *Nature*. The water — enough to fill Earth's oceans 5 times over — may eventually be incorporated into new planets.

The solar system consists of the star IRAS-4B, still surrounded by the cool, ice-rich, gaseous cloud from which it formed. A dusty "protoplanetary disk," similar to the disk that gave birth to Earth 4.5 billion years ago, encircles the star.

Spitzer observations revealed ice particles rain out of the gas cloud at supersonic speed and land in the dusty disk, where the ice flashes into water vapor. Spitzer can measure the water vapor because it glows in the infrared.

The star system is less than 10,000 years old — too young for planets, moons, comets, and asteroids to exist yet. It offers a rare opportunity to study the earliest phase of solar system evolution, including the role water plays in the process, says Dan M. Watson, an astrophysicist at the University of Rochester in New York and lead author of the report.

"For the first time," Watson says, "we are seeing water being delivered to the region where planets will most likely form." — **D. P.**

Longer-lived oceans on Venus?

Scientists may have to add Venus to the growing list of places in the solar system to search for evidence of past life. Venus' oceans may have persisted far longer than scientists thought — possibly long enough to have spawned primitive life.

David Grinspoon of the Denver Museum of Nature and Science and Mark Bullock of the Southwest Research Institute reported the finding October 10 at the meeting of the American Astronomical Society's Division for Planetary Sciences in Orlando, Florida.

On Venus, a runaway greenhouse effect in the planet's carbon-dioxide rich atmosphere long ago raised temperatures so high its oceans boiled away. But how long did it take? Earlier models suggested a lifetime of just 600 million years. But those models failed to take into account water clouds in the atmosphere, which would have delayed the oceans' fate.

In Grinspoon and Bullock's new model, venusian oceans could have survived at least a billion years, and perhaps for as long as 2 billion. The researchers said future Venus landers could resolve the debate by analyzing rock samples.

If Grinspoon and Bullock are right, Venus would have been habitable for a sizable fraction of the solar system's history. And if Earth is any indication, 1 to 2 billion years would have been plenty of time for simple life-forms — such as single-celled organisms — to gain a foothold. — **R. T.**

Stars form in a galaxy's "tail"

Scientists observed stars forming in the outer region of a galaxy's comet-like tail some 220 million light-years from Earth. The finding suggests star formation occurs more frequently between galaxies than previously believed. The results are scheduled for publication in the December 10 issue of *The Astrophysical Journal.*

Using NASA's Chandra X-ray Observatory and the Southern Astrophysical Research Telescope in Chile, scientists probed 29 regions in the galaxy ESO 137-001's tail containing ionized hydrogen gas. The gas in these regions is so hot, its atoms shed electrons, leaving electrically charged particles.

Ionized hydrogen indicates star formation. As the galaxy races toward the center of galaxy cluster Abell 3627, it leaves newly formed stars in its wake. — **L. L.**

X-RAY: NASA/CXC/MSU/M. SUN ET AL; H-ALPHA AND OPTICAL: SOAR (MSU/NOAO/UNC/CNPQ-BRAZIL)/M. SUN ET AL.

LEFT BEHIND. **The galaxy ESO 137-001 leaves a trail of young stars in its wake.**

Top 10 *space stories of 2007*

IN 2007, SCIENTISTS explored the outcome of the Milky Way's coming collision with the Andromeda Galaxy (M31). Planet-hunters bagged transiting worlds the size of Neptune — and came a step closer to an exo-Earth. Comet McNaught (C/2006 P1), seen here above Santiago, Chile, gave skygazers a celestial surprise.

ANTENNAE GALAXIES (TOP LEFT): NASA/ESA/STScI; NGC 2207 (TOP CENTER): NASA/STScI;
EXOPLANET ART (TOP RIGHT): ESA/C. CARREAU; COMET McNAUGHT: ESO/STEPHANE GUISARD

A brilliant comet stunned southern skywatchers, astronomers uncovered the most earthlike exoplanet yet, and physicists prepared to awaken their biggest machine ever. /// **BY FRANCIS REDDY**

The past year brought thrills to southern observers, who witnessed an amazing sky show by the brightest comet in decades. Astronomers discovered ever smaller worlds around other stars, made the first 3-D maps of dark matter, and took a close look at what will happen when the Andromeda Galaxy (M31) collides with the Milky Way.

Closer to home, NASA's Pluto-bound New Horizons spacecraft swung past Jupiter, and the Cassini probe, now orbiting Saturn, revealed a full-fledged sea on the planet's largest moon. A sophisticated satellite put relativity to the test, and physicists completed a machine beneath France and Switzerland that they hope will find the origin of mass.

Astronomy's editors ranked these and other findings and assembled this countdown of 2007's biggest stories.

Francis Reddy *is a senior editor of* Astronomy.

THE COMET shone in daylight January 14 following its closest approach to the Sun. ROB RATKOWSKI

10 Nights of the comet

Comet McNaught, the brightest comet in 42 years, took everyone by surprise. On August 7, 2006, Scottish astronomer Robert McNaught at Australia's Siding Spring Observatory imaged the 17th-magnitude comet using the 0.5-meter Uppsala Schmidt Telescope. Officially cataloged as C/2006 P1, Comet McNaught gave no hint its brief visit would be the least bit noteworthy.

As 2007 opened and the comet neared the Sun, it brightened rapidly and put on a nice show for skywatchers in the Northern Hemisphere. By January 11, McNaught had reached magnitude –3, outshining every star and planet except Venus. Despite the comet's low altitude and the presence of bright twilight, people who just happened to be outside after sunset noticed it readily.

And it got better. On January 12, McNaught passed 15.9 million miles (25.5 million kilometers) from the Sun — less than half Mercury's distance. The next day, the comet's brightness peaked at magnitude –6, far outshining Venus. Observers who shielded the Sun from their eyes could pick out McNaught in broad daylight. The last comet so bright was 1965's Ikeya-Seki.

After swinging around the Sun, McNaught became an evening sight for Southern Hemisphere observers. By January 17, as the comet rose out of twilight, a spectacular dust tail appeared. Particles ejected by the comet's icy nucleus in the months, weeks, and days before it rounded the Sun formed a broad, striated fan at least 35° long. Even after the comet disappeared from view for northern observers, parts of this enormous tail remained visible as faint, eerie bands.

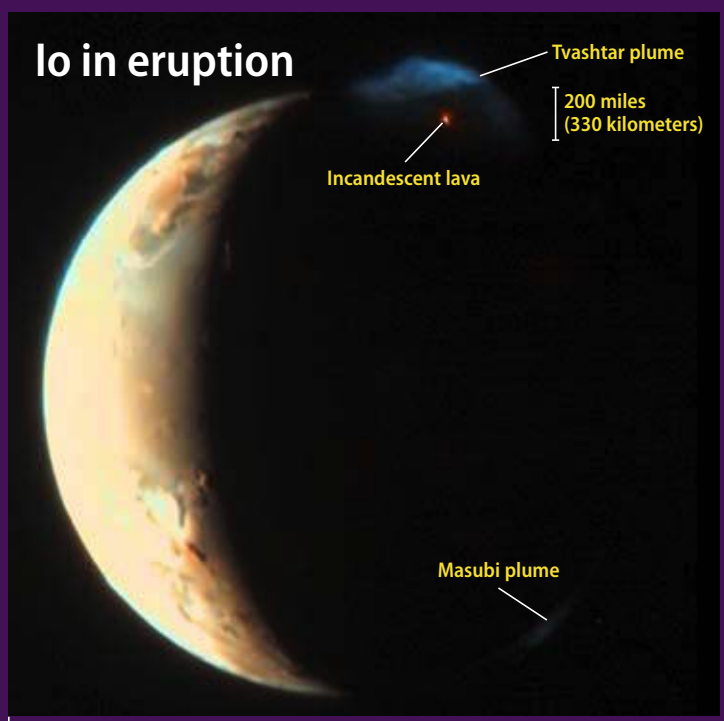
The comet faded rapidly, but remained a naked-eye sight into February. By chance, the U.S. and European Ulysses probe flew almost directly behind McNaught as the month opened. The craft spent a record 5 days sampling tail gases 160 million miles (257 million km) from the comet's icy nucleus.

After McNaught, skygazers can only wonder when the next brilliant comet will surprise us.

ASTRONOMERS discovered the first transiting ice giant, illustrated here, orbiting the red dwarf GJ 436. The planet is about a third more massive than Neptune. ESO

9 Zeroing in on exo-Neptunes

In 2007, astronomers' tally of planets found around other stars crested 250. Exciting new finds included the smallest-known transiting exoplanet and the first Neptune-mass world found in a star's



NEW HORIZONS captured Jupiter's volcanic moon Io as no spacecraft has done. The bright orange glow of hot lava punctuates an enormous blue plume from the volcano Tvashtar. Eruption plumes from other volcanoes arc above the moon's dark limb. The spacecraft captured this image 19 hours after its February 28, 2007, closest approach, 1.4 million miles (2.3 million km) from Io. JHUAPL/SwRI

habitable zone. The surface of a planet in a star's habitable zone can retain liquid water for long periods — a minimum requirement for the development of life as we know it, say scientists.

In April, Michael Gillon at Liege University, Belgium, led a team that observed the first passage of an ice-giant planet in front of its star. Every 2.6 days, a Neptune-sized world transits the red dwarf GJ 436, 30 light-years from Earth.

The transits allowed Gillon and his colleagues to pin down the planet's mass at 22.4 Earths, or about a third more massive than Neptune. They also let scientists compute the planet's density — twice that of water. This led planet-hunter Geoff Marcy of the University of California, Berkeley, to describe GJ 436b as a "hybrid super-Earth/Neptune." High-temperature water maintained in solid form by pressure may surround the planet's rocky core.

Planets around another red dwarf made headlines, too. In 2005, a team of Swiss, French, and Portuguese astronomers discovered a 15-Earth-mass planet around Gliese 581, 20.5 light-years away from Earth in Libra. In April 2007, the same team announced two additional lower-mass planets orbit the star.

The smaller of the two new worlds, 5-Earth-mass Gl 581c, orbits the star every 13 days — and lies within its habitable zone. That's important because if Gl 581c is a rocky, earthlike world instead of a Neptune-type ice giant, pools of liquid water could exist on its surface.

A month later, a study led by Werner von Bloh at the Potsdam Institute for Climate Impact Research in Germany demonstrated

THREE PLANETS orbit the red-dwarf Gliese 581. The system, shown in this artist's conception, includes the first Neptune-like ice-giant found within a star's habitable zone. ESO

Gl 581c's orbit carries the planet too close to the star for any surface water to remain liquid.

But the scientists found the orbit of 8-Earth-mass Gl 581d actually straddles the habitable zone's outer edge. "Despite the adverse conditions on this planet, at least some primitive forms of life may be able to exist on its surface," the team concluded.

8 New Horizons encounters Jupiter

On February 28, 2007, NASA's New Horizons spacecraft flew by Jupiter. The probe captured the most detailed images of the giant planet and its moons in 4 years.

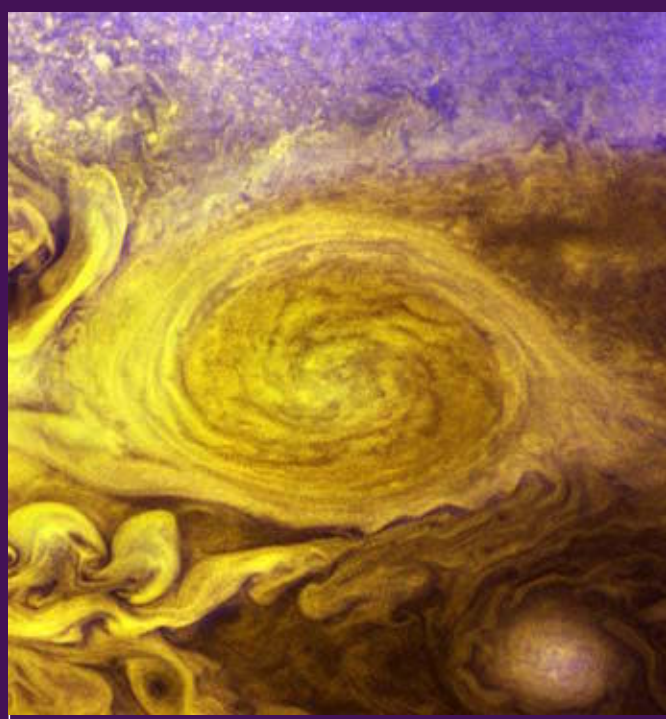
"From the first close-up look at the Little Red Spot storm, to the best views ever of Jupiter's rings, to sequences of a volcanic eruption on the jovian moon Io, we've seen some amazing things," says Hal Weaver, a mission scientist at Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland.

"The data are better and richer than we ever expected," says lead researcher Alan Stern at NASA Headquarters in Washington.

New Horizons caught Io's Tvashtar volcano launching a spectacular 200-mile-high (330 kilometers) umbrella-shaped cloud. The probe's high-resolution cameras mapped Jupiter's four big moons — Io, Europa, Ganymede, and Callisto — in unprecedented detail.

After passing the planet, the spacecraft sped nearly 100 million miles (160 million km) along Jupiter's magnetotail, an ionized-gas structure the solar wind sweeps behind the planet. Measurements revealed unexpected structure and organization in this previously uncharted environment.

By the end of June, the spacecraft had beamed back enough Jupiter data to fill a DVD. But this isn't its main mission. Designed to provide the first close-up look at Pluto and its moons, New Horizons needed a 9,000-mph (14,400 km/h) speed boost from Jupiter in order to reach its target by July 2015.



JUPITER'S NEWEST RED SPOT is the second-largest storm on Jupiter. Roughly 70 percent of Earth's size, the storm began turning red in late 2005. This false-color portrait from NASA's New Horizons probe shows details as fine as 9 miles (15 km) across. That's about 10 times the resolution of the Hubble Space Telescope. JHUAPL/SwRI

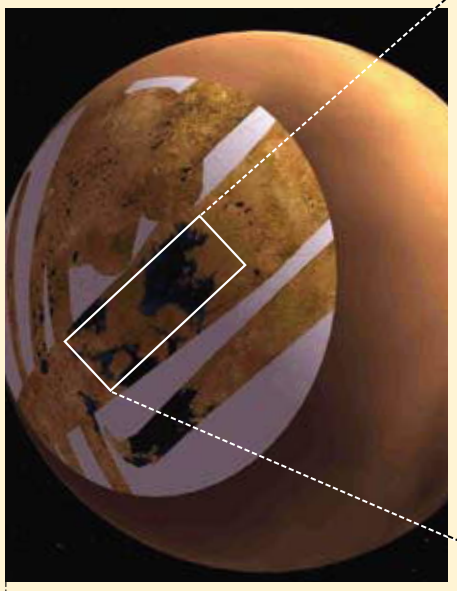
7 Cassini spies Titan's "Black Sea"

As NASA's Cassini spacecraft flew near the north pole of Saturn's largest moon February 22, its radar partially imaged a lake so big mission scientists are calling it a sea. What Cassini saw indicates this plus-sized pond takes up a greater percentage of Titan's real estate than the Black Sea does here on Earth.

The spacecraft, in orbit around Saturn since mid 2004, uses a radar beam to punch through Titan's smoggy atmosphere. The instrument has found numerous dark, smooth areas planetary scientists believe are lakes. "We've long hypothesized about oceans on Titan and now, with multiple instruments, we have a first indication of seas that dwarf the lakes seen previously," says Jonathan Lunine, a planetary scientist at the University of Arizona, Tucson.

While Cassini researchers lack definitive proof the terrain contains liquid, they find themselves increasingly comfortable with this conclusion. The surface smoothness, shore-like contours, and other properties of these features make it difficult to call them anything but lakes.

So, what are they filled with? Titan's frigid atmosphere holds much methane and ethane. Scientists expect any surface fluids will be a cocktail of these two substances.



EACH TIME Cassini sweeps over Titan, the craft's radar reveals another strip of the smoggy moon's surface. NASA/JPL/USGS

6 Welcome to Milkomeda

An oft-cited tidbit of astronomical lore is the pending collision between the Andromeda Galaxy (M31) and the Milky Way. In May, T. J. Cox and Abraham Loeb at the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, presented the most detailed analysis yet of the future cosmic crash and its aftermath. The study showed the collision will happen sooner than previously thought — and may include a surprising twist for the solar system.

AT THEIR FIRST ENCOUNTER 2 billion years hence, Andromeda and the Milky Way may resemble NGC 2207 (left) and IC 2163. The interacting galaxies lie 114 million light-years away in Canis Major. NASA/HUBBLE HERITAGE (STScI)

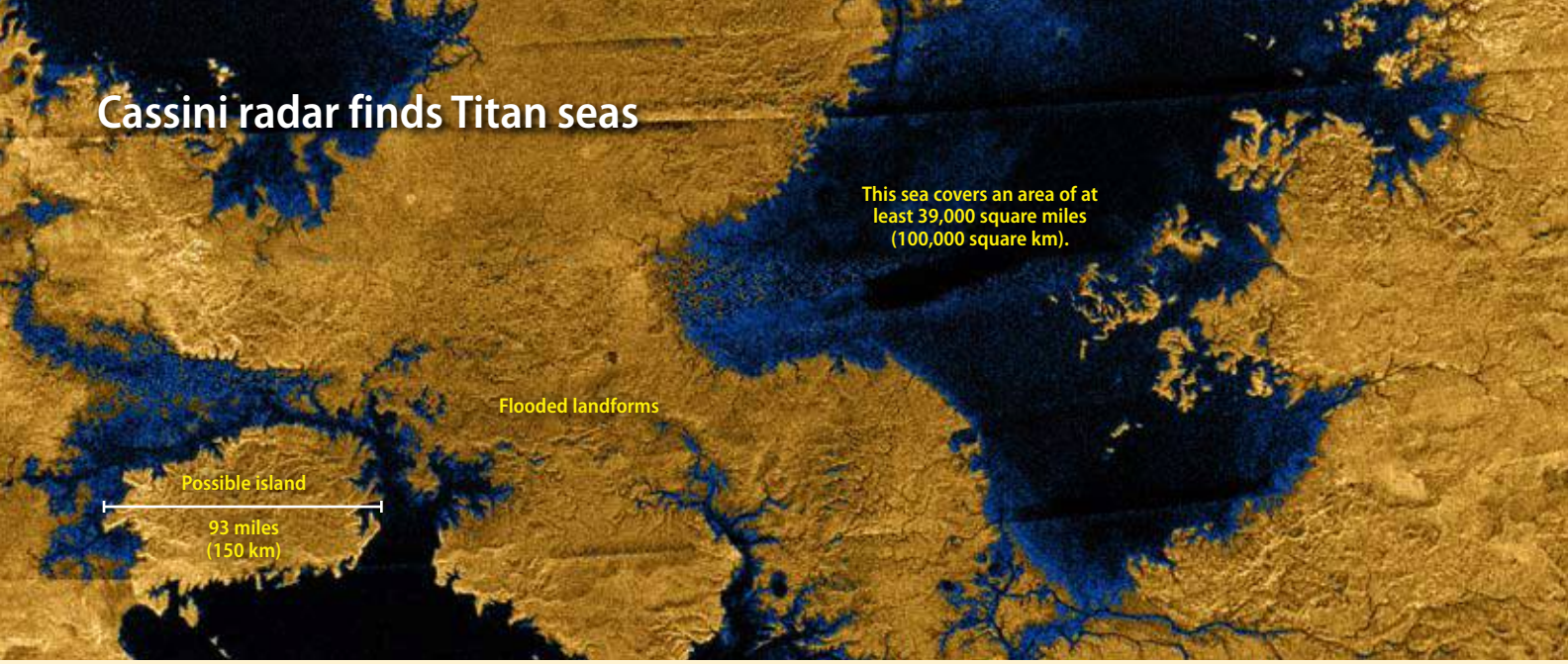
The researchers developed new computer models of both galaxies — including the gas and dark matter between them — and then simulated the crash. The two great spirals approach and pass one another multiple times before finally merging, and each interaction creates long tidal tails of stars. The merged object, which Loeb dubbed Milkomeda, undergoes only a modest increase in star formation. By the time the merger is complete, both galaxies will have used up most of their available gas quiescently making stars.

The most surprising aspect, say the researchers, is that the merger will take place within 5 billion years — before the Sun will burn out. The first pass will occur only 2 billion years from now, at least a billion years earlier than previous estimates. Intergalactic material and the galaxies' dark-matter halos sap much of the galaxies' orbital energy, which results in an earlier collision.

Another surprise was the solar system's fate. The astronomers compute a 10-percent chance the collision will sweep the Sun, its planets safely in tow, into one of those tidal streamers during the galaxies' first encounter. The next time around, there's a 50-50 chance the solar system will be cast out.

One unexpected possibility: The Sun could switch galaxies and become bound to M31 before the merger. "In effect, Andromeda will capture the Sun, and future astronomers in the solar system might see the Milky Way as an external galaxy in the night sky," Loeb muses. An exciting outcome, certainly, but the astronomers emphasize it's also an unlikely one. They compute only a 2.7-percent chance M31 will steal the solar system.

"The motivation for the study came from work I did in 2001 about the observational implications of living in an accelerating universe," Loeb explains. In the future, all distant galaxies will accelerate away from us, eventually reach the speed of light relative to us, and then fade from our view. Andromeda is the only massive galaxy that will remain bound to the Milky Way. "If you want to do extragalactic astronomy," Loeb jokes, "you'd better do it now."


Cassini radar finds Titan seas
This sea covers an area of at least 39,000 square miles (100,000 square km).
Flooded landforms
Possible island
93 miles (150 km)

CASSINI'S IMAGING RADAR scanned Titan's surface February 22. Brightness indicates rougher terrain. Bright, jutting shorelines suggest eroded and flooded landforms, and an island as large as Hawaii's Big Island appears in one lake. The largest lake, at far right, wasn't completely imaged. But what Cassini saw covers a greater fraction of Titan's surface than the Black Sea does on Earth. NASA/JPL/USGS

5 A stellar fossil uncovered

HE 1523–0901, an 11th-magnitude red giant, turns out to be one of the oldest stars known: 13.2 billion years. This means HE 1523–0901 formed about 500 million years after the Big Bang.

Studies of the cosmic microwave background indicate the universe's first stars fired up about 400 million years after the Big Bang. Astronomers think these stars were extremely massive, tipping the scales at hundreds of Suns.

"The lifetime of the very first stars was rather short — a few hundred million years," says Anna Frebel at McDonald Observatory in Texas. At the ends of their lives, these stars exploded as supernovae and seeded the cosmos with new elements. Carbon and iron, so important for planets and life today, simply didn't exist in the universe until then.

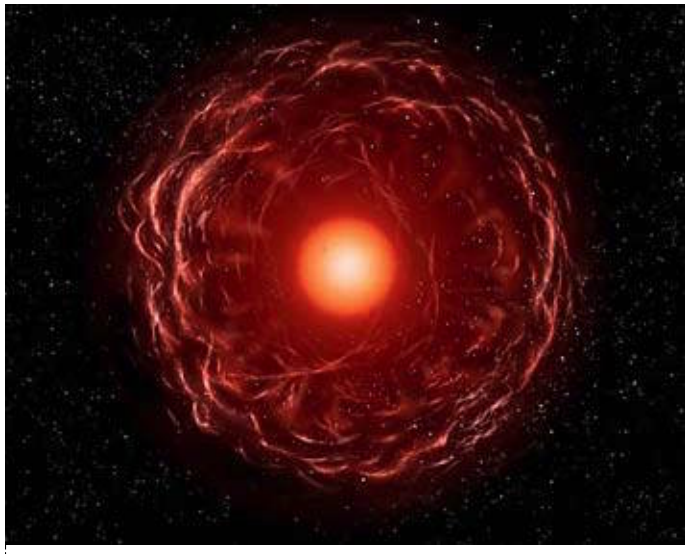
To learn about the first stars, Frebel and her colleagues seek out the Milky Way's oldest stars, those with the smallest proportions of iron. That's where HE 1523–0901 comes in. The iron-poor star also contains the greatest amount of radioactive uranium ever found. "Very few stars display radioactive elements," Frebel says. "I'm looking at a rare subgroup of these already rare stars."

Because uranium decays over time, it serves as a natural timekeeper. Better yet, the spectrum of Frebel's uranium star shows other natural "clocks" — thorium, osmium, iridium, and europium. "We can now use several different ratios of different elements, not just one as in the past for a few other stars," explains Frebel. It's this fact that makes her findings so certain.

Theorists provide a starting point by estimating how much of these "clock" elements the first stars produced. HE 1523–0901 and stars like it will help astronomers get a handle on how hot and massive those short-lived first stars were.

Studying these ancient stars also helps constrain state-of-the-art simulations of the early universe. "Only now are computers getting powerful enough to carry out big simulations," says Frebel. "But the results need to be compared with observations, and the old stars I'm working on are the perfect pieces to the puzzle."

When HE 1523–0901 lit its nuclear fires, the Sun's birth lay 9 billion years in the future. Is it fair to take a bit of poetic license and call this star a witness to the birth of our galaxy? "Well," Frebel says, smiling, "I guess that isn't so far from the truth."



HE 1523–0901, ILLUSTRATED HERE, is one of the oldest stars known. The 0.8-solar-mass red giant lies 7,500 light-years away in Libra. Astronomers determined the star's 13.2-billion-year age thanks to a rare combination of "cosmic clock" elements. ESO

DID A STAR like Eta Carinae spawn the second-brightest stellar explosion on record? Astronomers suggest Supernova 2006gy erupted from a star that tipped the scales at more than 100 solar-masses. Such massive stars may explode when their cores disintegrate. NASA/ESA/NATHAN SMITH AND JON MORSE (UNIV. OF COLORADO)

4 A tale of two supernovae

In May 2007, a team of astronomers led by Nathan Smith at the University of California, Berkeley, crowned Supernova 2006gy the most luminous supernova on record. But the reign of this "supernova king" lasted only until October. That's when Robert Quimby at the University of Texas in Austin and his colleagues announced an earlier, even brighter blast.

Quimby heads the Texas Supernova Search project, which discovered both events. The search caught Supernova 2006gy on the rise September 18, 2006, near the core of galaxy NGC 1260, some 238 million light-years away. With a peak luminosity of 50 billion Suns, 2006gy was 10 times brighter than the average type Ia supernova and 100 times brighter than a representative type II.

But in October 2007, following a lengthy analysis, Quimby's team announced an earlier event, named 2005ap, actually shone roughly 2 times brighter than 2006gy.

Explaining either of these superbright supernovae is a challenge. Smith's team thinks 2006gy could be the first case of a supernova triggered by a theoretical process first described 40 years ago: pair instability. A star with more than 100 times the

3 The first 3-D map of dark matter

In January 2007, an international team of astronomers presented the first three-dimensional map of dark matter. The project, called the Cosmic Evolution Survey (COSMOS), is the largest ever undertaken with the Hubble Space Telescope.

Dark matter — a substance known only through its gravitational effects on normal matter, like stars, planets, and galaxies — accounts for most of the universe's mass. "For the first time, we've been able to map out this invisible and mysterious dark matter," says Caltech's Richard Massey, who headed the Hubble side of the research team.

Using the space telescope's Advanced Camera for Surveys, astronomers acquired 575 images covering a 2-square-degree patch in Sextans. "This is 9 times larger than any previous Hubble survey," notes Nick Scoville, also at Caltech, who led the overall project. The milestone study required nearly 1,000 hours of Hubble time over 2 years.

The project also needed 400 hours of observations with the European Space Agency's XMM-Newton X-ray satellite. XMM-Newton mapped hot, X-ray-emitting gas in galaxy clusters within the survey region. The gas makes up about 4 times the stellar mass in these clusters. The European Southern Observatory's Very Large Telescope in Chile and the Canada-France-Hawaii, Subaru, and Keck telescopes in Hawaii provided color information that allowed the astronomers to determine the galaxies' distances.

But the Hubble images allowed the team to glimpse weak gravitational lensing — distortions in the shapes of background galaxies caused by the light-bending gravity of intervening dark matter. The result is a 1- to 2-percent distortion of each galaxy's shape.

"We understand statistically what those galaxies are supposed to look like," Massey says. "As the light gets deflected, it distorts the shapes of the background galaxies. So, we end up seeing them in a distorted way, as if through lots of little lenses — and each of those lenses is a bit of dark matter."

"This is the first clear view of the cosmic web," says team member Richard Ellis, also at Caltech. The largest visible structures are filaments spanning 60 million light-years and containing some 2 trillion times the Sun's mass. But because the COSMOS map includes information about the objects' distances, it's also the first direct measure of galaxy growth over time. More distant "slices" of the map show the universe's state at earlier times.

"Dark matter collapsed first," says Massey. "Without it, the universe as we know it today wouldn't exist." The COSMOS map shows visible galaxies then formed within the framework the dark matter established.

"This is a tremendously exciting time," notes Ellis. Weak lensing, he says, has become one of cosmology's basic tools.

Sun's mass eventually forms an oxygen core so hot that colliding gamma rays spontaneously create a pair of particles — an electron and a positron.

Formation of these particles removes pressure from the core, which begins to collapse, then detonates in runaway thermonuclear reactions. This may one day be the fate of Eta Carinae, one of the most massive stars known.

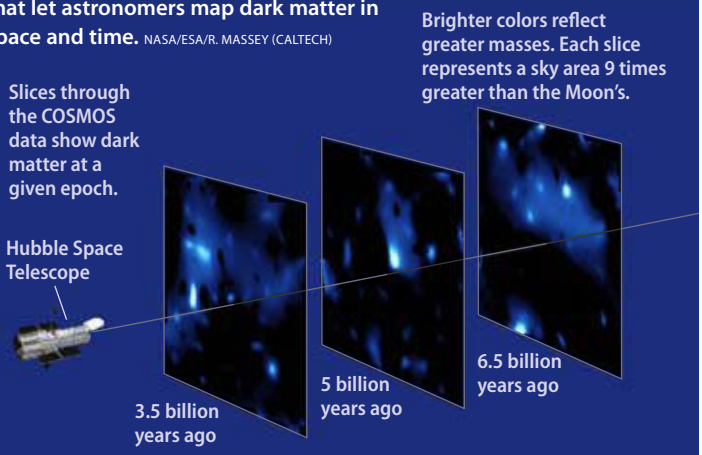
"That's why 2006gy is so exciting to us," Smith explains. "It may finally give us some evidence this process actually works in nature." Most of a supernova's light comes from the radioactive decay of nickel-56, an isotope formed in the blast. "But, if 2006gy is our guide," he says, "a pair-instability explosion could release 100 times more nickel than a normal supernova."

The pair-formation model fits 2006gy, which remained exceptionally bright for more than 200 days. But it can't explain 2005ap, which quickly rose to and fell from its record-setting peak luminosity. In fact, Smith says, the star's behavior appeared similar to a normal type II, just much brighter.

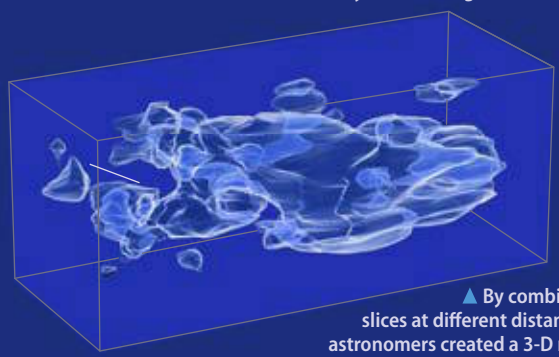
The Texas Supernova Search found 2005ap March 3, 2005, in a dwarf galaxy some 4.7 billion light-years away. This distance initially made Quimby doubt the find was a supernova, but observations he received from Keck Observatory, Hawaii, in December 2006 changed his mind. The explosion's spectra are so unusual, he says, "It took some time for me to put all the pieces together and convince myself that it was, in fact, a supernova — and the most luminous one ever, at that."

Astronomers map dark matter in 3-D

HUBBLE, XMM-NEWTON, and powerful ground-based telescopes provided data that let astronomers map dark matter in space and time. NASA/ESA/R. MASSEY (CALTECH)


Brighter colors reflect greater masses. Each slice represents a sky area 9 times greater than the Moon's.
Slices through the COSMOS data show dark matter at a given epoch.
Hubble Space Telescope
3.5 billion years ago
5 billion years ago
6.5 billion years ago

▲ Dark-matter clumps appear more pronounced in recent times (left) than in the early universe (right).



▲ By combining slices at different distances, astronomers created a 3-D map.

ENGINEERS LOWERED this massive end cap for the Compact Muon Source (CMS) experiment into the Large Hadron Collider (LHC) cavern January 9, 2007. CERN/MAXIMILIEN BRICE

2 Monster machine

After some minor setbacks in 2007, technicians have begun commissioning the world's biggest scientific instrument — the Large Hadron Collider (LHC). Scientists expect to conduct the first high-energy science runs by summer.

For the past 13 years, the LHC has been taking shape a few hundred feet beneath France and Switzerland. Its mission is straightforward: Recreate conditions not seen in the universe since less than a billionth of a second after the Big Bang.

The $8 billion facility is the brainchild of the European Organization for Nuclear Research (CERN) in Geneva. The LHC will accelerate trillions of protons in opposite directions inside two pipes around a ring 17 miles (27 km) in circumference. Superconducting magnets cooled to –456° F (–271° C) will bend the beams around the ring. Traveling at 99.9999991 percent the speed of light, the particles will make the trip more than 11,000 times a second.

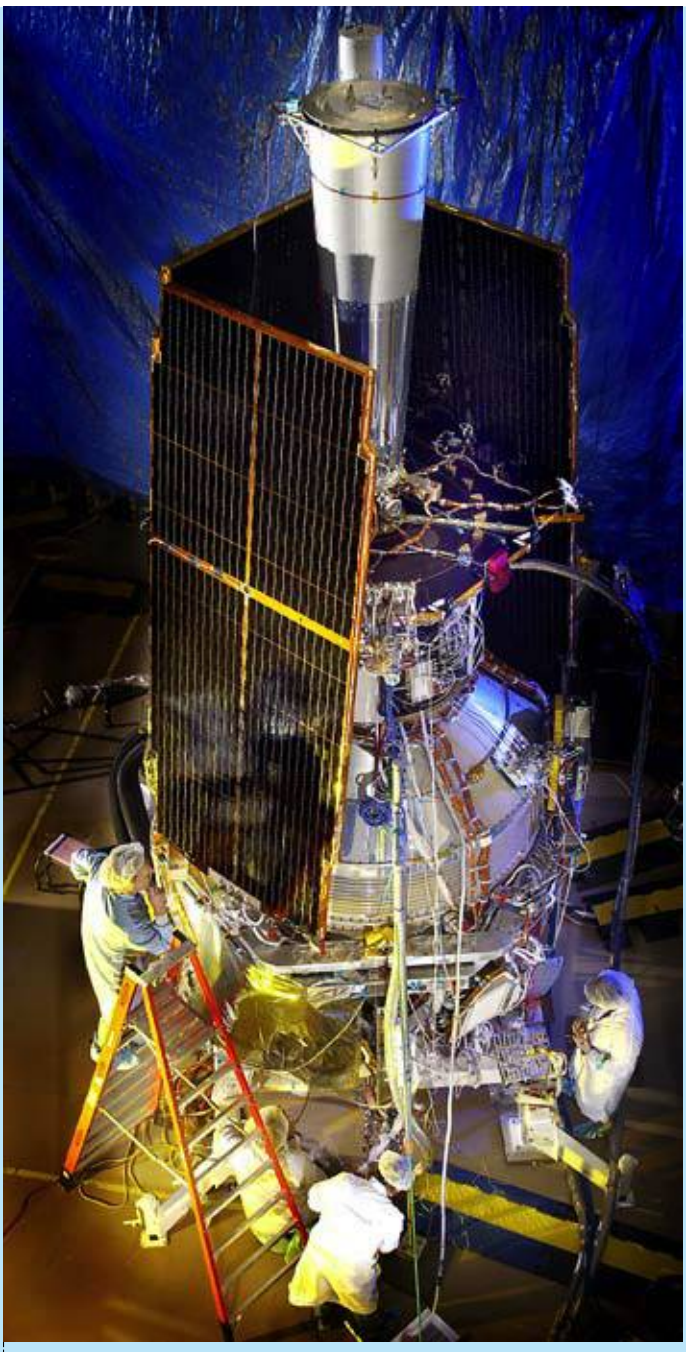
As the two beams enter detectors built along the ring, magnets deflect them so some of the protons collide. The two primary experiments — called ATLAS and CMS — are the most sophisticated ever built. (ATLAS alone weighs 7,000 tons, the equivalent of about 100 jumbo jets.) These experiments will

record the wreckage of up to 600 million proton collisions each second. The flood of data could fill enough CDs to reach the Moon and back twice each year. To deal with it, CERN — the laboratory that brought us the World Wide Web — developed a system that harnesses tens of thousands of computers around the globe.

Highest on physicists' list of LHC objectives is finding the Higgs boson, the particle thought to confer mass to every other particle. "Discovering the Higgs boson — or perhaps a set of them — and measuring their properties will be crucial to refining our thinking about the universe just after the Big Bang," explains Michael Barnett, a physicist at Lawrence Berkeley National Laboratory and a member of the ATLAS team.

But that's just the beginning. Other finds could include new particles responsible for dark matter or even mini black holes. "I would love to see evidence for extra dimensions," he says. This would raise scientists' hopes that string theory — a candidate unified physical theory that lacks experimental verification — is real.

How great an advance over existing particle accelerators does LHC represent? In terms of the number and speed of particle collisions, says Barnett, "It's like replacing the old ferry across San Francisco Bay with the Golden Gate Bridge." But he thinks of the facility's importance in far grander terms. "The ATLAS and CMS experiments have the potential to transform our thinking about the universe in the way that Copernicus and Einstein did," he says.



RUSS UNDERWOOD/LOCKHEED MARTIN CORPORATION

TECHNICIANS INSTALL THE SOLAR PANELS that powered GP-B, arguably the most sophisticated unmanned spacecraft ever flown.

1 Putting Einstein to the test

Scientists designed NASA's Gravity Probe B (GP-B), a $750 million polar-orbiting satellite launched in 2004, to make the most stringent tests of general relativity ever attempted. Einstein passed with flying colors.

"We're very happy about the mission," says lead researcher Francis Everitt. "We'll be even happier when we've done all the data reduction." After 18 months of painstaking analysis, the GP-B team released preliminary results in April. Months of work remained, however, to understand subtle differences between the experiment's four gyroscopes. The researchers expected to present their final report in early December 2007.

While Einstein's 1916 theory of gravity has earned its place as a cornerstone of modern physics, it remains poorly tested. "In the realm of black holes and the universe," Caltech physicist Kip Thorne once put it, "the language of general relativity is spoken, and it is spoken loudly. But in our tiny solar system, the effects of general relativity are but whispers."

By 1960, two physicists, George Pugh at the Pentagon and Leonard Schiff at Stanford University, independently suggested orbiting gyroscopes could measure these subtle effects, and GP-B was born. Everitt joined the project in 1962; NASA funding followed 2 years later.

"Nothing about this was easy," Everitt says. "Gravitational physics experiments are gruesomely difficult. You have to invent new technologies for them." By April 20, 2004, when GP-B blasted into orbit, the project had weathered no less than seven potential cancellations.

Yet, in essence, GP-B was simple. The satellite was basically a telescope, four gyroscopes, and a thermos bottle filled with supercold liquid helium. Once in orbit, the scientists pointed the telescope at a guide star, then they spun up the world's most precise gyroscopes on the same axis. Tiny thrusters maintained the telescope's lock on the guide star, but relativity's whispers ensured the gyros would not.

Everitt and his team estimated they'd be taking data 40 days after launch, but lots of small, unexpected problems cropped up. "It was 128 days before we could start gathering science.

Inside Gravity Probe B
Solar panels
IM Pegasi
Telescope
A telescope remained aligned to the guide star, IM Pegasi.
Gyroscopes
The spin axes of four gyroscopes also were initially aligned to the guide star.
Dewar
This vessel contained 645 gallons of liquid helium to keep the science experiment at –456° F (–271° C).
Micro thrusters
The probe's 16 cold-gas thrusters altered the spacecraft's orientation using boiled-off helium.

KATHERINE STEPHENSON (STANFORD UNIVERSITY)/LOCKHEED MARTIN CORPORATION

ONCE IN SPACE, Gravity Probe B locked its telescope onto a guide star. Scientists also aligned the gyroscopes' rotational axes with the star. Relativity manifested its effects by making the gyros precess.

Meanwhile, the helium is boiling away," he recalls. "Nerve-racking, but we finally got it."

General relativity predicts that an Earth-sized circle drawn in empty space will lose 1.1 inches (2.79 centimeters) in circumference when an Earth-mass is placed within it. This so-called geodetic effect is what made GP-B's gyros drift off the guide star, and it's readily apparent in the probe's 17.3 months of data. "You can see the relativity staring you in the face," Everitt says.

A second, more subtle, effect, called frame-dragging, has not yet fully revealed itself. This twist in space-time occurs near rotating masses. Everitt explains the data show "clear hints" of frame-dragging, but the case isn't yet rock solid.

The geodetic results, however, agree with Einstein's predictions to within 1 percent. And the team hopes its final analysis will improve on this value by about 100 times.

WEB EXTRA To read more about these stories, visit www.Astronomy.com/toc.

GRAVITY PROBE B sported the world's most spherical gyroscopes. Each is an almost perfect 1.5-inch (3.81 centimeters) polished sphere made of specially-fused solid quartz. Enlarge one of these spheres to Earth's size, and the highest peak or deepest valley would lie only 8 feet (2.44 meters) from sea level. DON HARLEY

QUICK LOOK

NEWS STORIES TO WATCH IN 2008

- **JULES VERNE, the European Space Agency's new Automated Transfer Vehicle, will launch to the International Space Station in January.**
- **ON JANUARY 15, NASA's MESSENGER probe will return the first close-up images of Mercury in 33 years.**
- **IN OCTOBER, MESSENGER makes a second Mercury flyby.**
- **NASA'S PHOENIX probe lands on Mars May 26.**
- **INDIA'S LUNAR ORBITER, Chandrayaan 1, will launch in late June, and NASA's Lunar Reconnaissance Orbiter will follow it by year's end.**

The biggest planet's 5 deepest mysteries

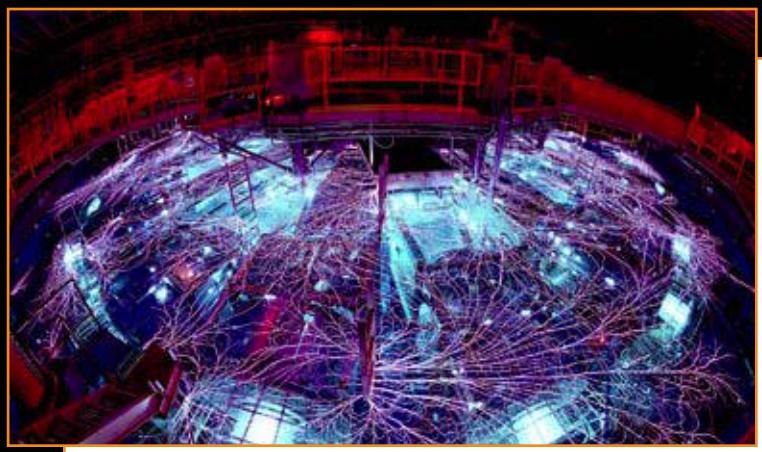
From its inner core to its far-ranging magnetic field, Jupiter tightly guards its secrets. /// **BY MICHAEL CARROLL**

In the past 35 years, seven NASA spacecraft have flown past Jupiter. Two Pioneer and two Voyager probes performed the initial reconnaissance, showing intricate details of the planet's meteorology as well as volcanoes on Io and an icy crust on Europa — two of Jupiter's wondrous moons. In subsequent years, Ulysses, Cassini, and, most recently, New Horizons each viewed Jupiter on the way to their prime targets.

Only one mission reached Jupiter and stayed. The Galileo orbiter and probe studied the giant planet and its environment in depth between 1995 and 2003. Not surprisingly, Galileo returned far more data in its 8 years than all the other missions combined — enough data to answer many of the questions planetary scientists were asking about Jupiter and its moons.

Yet, the robotic explorer left many mysteries in its wake. "Galileo demonstrated that there is something fundamentally wrong with our theories of planetary formation," says Scott Bolton of the Southwest Research Institute (SwRI) in San Antonio. While Bolton helps design an advanced probe to orbit Jupiter, other researchers explore closer to home to unravel the many unsolved mysteries about the nature and origin of the king of worlds.

GIANT JUPITER and its roiling atmosphere posed for the Cassini spacecraft in 2000. Decades of close-up observations have revealed much about Jupiter and its moons, but there's still plenty to learn. NASA/JPL/SSI



SANDIA'S Z MACHINE generates intense electric currents that mimic — for roughly a millionth of a second — conditions at Jupiter's heart. SANDIA NATIONAL LABORATORIES/RANDY MONTOYA

1 What's the nature of Jupiter's core?

There's a bit of Jupiter residing right here on Earth. It exists — for nanoseconds at a time — in a lightning-laced chamber at Sandia Laboratories in New Mexico. Sandia's "Z machine," the most powerful electrical device in history, recreates conditions in Jupiter's core. The machine is 108 feet wide (33 meters) and comprises several concentric "doughnuts." Giant 90,000-volt capacitors stand in a 20-foot-deep (6m) pool of oil, which rings an inner pool of deionized water. Devices submerged within this toroidal pool amplify the capacitors' energy, channeling it into a central vacuum chamber at the structure's core. A 50-trillion-watt electrical pulse plows into its center.

"In one-tenth of a millionth of a second, we generate 80 times the entire power output of the world," says Sandia's Chris Deeney. Pressures at the core can reach a whopping 3.25 million atmospheres. Scientists think this pressure mimics the conditions that exist in Jupiter's interior, where hydrogen is stripped of its electrons and becomes, in effect, a liquid metal.

"We'd love to know what Jupiter's [internal structure] is like," says Andrew Ingersoll of the California Institute of Technology. "There are two uses for the word 'core.' The first refers to rock, metals, and liquid water. This central region probably doesn't extend out beyond 10 percent or so. Then, a liquid metallic hydrogen layer extends out perhaps 80 percent."

Engineers who run Sandia's Z machine work with scientists who attempt to model Jupiter's interior in supercomputers. One such researcher is Los Alamos Laboratory's Didier Saumon.

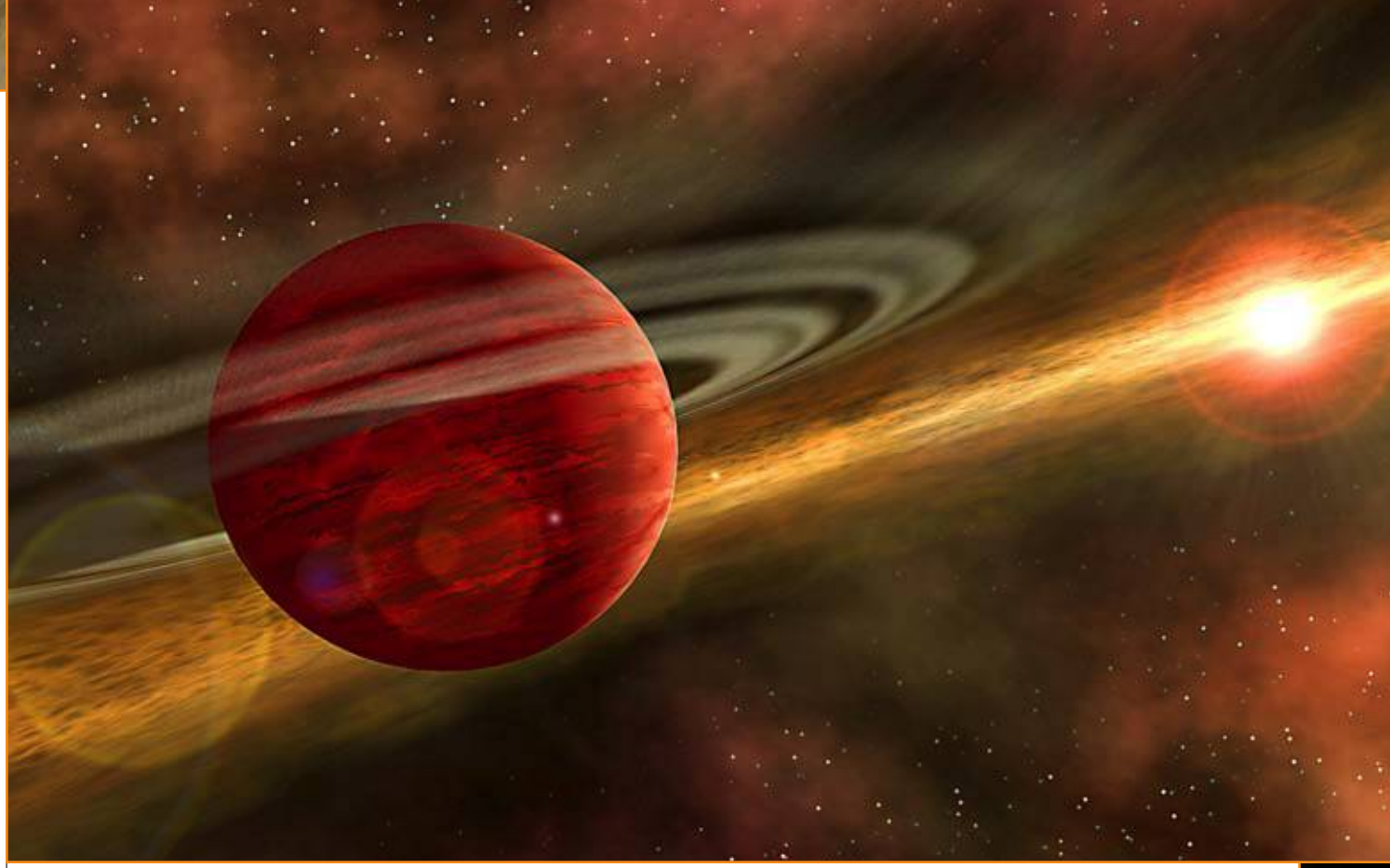
"Our theories make predictions," he explains. "The engineers then design an experiment, and we compare our models to what comes out. It's a simple model, really, compared to reality — we have so little information, we cannot know the details." Saumon and colleagues like Tristan Guillot use a three-tiered model consisting of a solid core wrapped in a shell of liquid metallic hydrogen and surrounded by outer gas layers. They refer to this as a "toy model." "We've calculated 50,000 models, and rejected the ones that are not in agreement."

Ironically, the structure of Jupiter's interior may be revealed by the planet's cloud tops. "Superficially, Jupiter has a very turbulent atmosphere," says Ingersoll. But the atmospheric bands are extremely stable. They have remained essentially unchanged for a century. "Do the bands have deep roots?" asks Ingersoll. "It's possible. The belts may be arranged as nested cylinders that are concentric to the axis of rotation. This would set up tremendous centrifugal forces. When you start moving that sort of mass around, it affects the gravity field of the planet."

Bolton and engineers at SwRI are banking on that gravity effect as they draw plans for the next mission to Jupiter. The Juno project is designed to make a detailed map of Jupiter's gravity field. Juno flight engineers will monitor carefully the spacecraft's orbit. As Jupiter's gravity tugs on Juno, the spacecraft will change speed — an effect that will show up as a subtle shift in the frequency of the probe's radio signals. Such measurements will enable researchers to determine the size and mass of Jupiter's core.

Says Ingersoll, "By looking at the gravity from equator to pole, you can see if Jupiter is operating on cylinders. If the field is smooth, the planet is rotating as a solid body. And if that's the case, we'd have to assume that those jet streams are skin deep. Which brings up the question: 'Why are they so long-lived?' If, on the other hand, the gravity field varies in specific ways, then the planet is, indeed, arranged in concentric cylinders."

OCEAN SWELLS of liquid metallic hydrogen may exist near Jupiter's core, where conditions are unlike any seen on — or in — Earth. MICHAEL CARROLL FOR *ASTRONOMY*



A JUPITER-CLASS PLANET starts to clear a path through the dusty protoplanetary disk from which it formed in this artist's impression. Understanding how Jupiter took shape will help astronomers studying the formation of extrasolar gas-giant planets. NASA/JPL-CALTECH/R. HURT (SSC)

2 How do gas-giant planets form?

Another sector of the scientific community wants to know about Jupiter's core: those who study planets orbiting other stars. "The importance of the core is raised as we search for extrasolar planets," says Bolton. "We see giant Jupiters all over the place, so Jupiter is our archetype for studying extrasolar systems."

Planetary dynamicist Hal Levison at SwRI says the size of Jupiter's core constrains how it formed. "The two general models are that either the core grows first and accumulates gases from the surroundings, or that Jupiter collapses directly from the solar nebula."

Both models have shortcomings. To better understand how gas-giant planets form, scientists need to know their composition. And the abundance of oxygen, in particular, is essential to understanding the genesis of giant planets.

To get at the oxygen abundance in Jupiter, scientists study how much water exists there. Jupiter formed far enough from the Sun's influence that our embryonic star's heat didn't destroy any volatile substances. So, Jupiter presumably soaked up the same ratios of materials present in the original solar nebula from which the Sun and planets grew. This means the amount of water in Jupiter depends on how much ice was present in the early solar nebula.

Michael Carroll *is an astronomical artist and science journalist in Littleton, Colorado. He wrote "Earth of the outer solar system," about Saturn's moon Titan, in the November 2007 issue.*

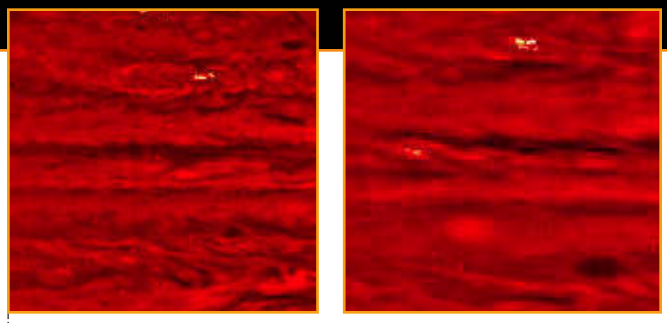
Unfortunately, measuring Jupiter's water abundance isn't easy. "Today, water has condensed into ice crystals [at Jupiter's cloud tops]," says Saumon. "Water in this form is incredibly hard to measure remotely. We need to measure it down where it's a liquid."

That's easier said than done. Galileo's atmospheric probe tried to map the abundance of water at various depths in Jupiter. "We thought we'd see more water," says planetary geologist Rich Terrile of NASA's Jet Propulsion Laboratory. "But the probe results didn't match anybody's models, so we have to assume that either the theory was wrong or the data were peculiar. It makes you uncomfortable to decide that the only data you have are not typical."

Scientists now believe the Galileo probe parachuted into a downdraft of unusually clear air, a vast hole in the planet's cloud deck. Because Galileo didn't get good water readings, it got little data on Jupiter's oxygen inventory. "The problem is that oxygen is the most abundant element in the universe next to hydrogen and helium," says Saumon. "We have no clue as to how much there is. We're missing a big piece of Jupiter's composition."

"Water is still the great mystery for me," adds Ingersoll. "Not only does it complete our inventory of oxygen and hydrogen in the solar system, but it's important to meteorology. We've seen magnificent lightning [at Jupiter]. Thunderstorms appear to feed all other meteorology, including the oval storms; they're at the bottom of the food chain. These storms are governed by water."

Galileo also missed Jupiter's upper ammonia cloud layer, so it failed to return data on Jupiter's abundance of nitrogen — the biggest component of Earth's atmosphere. Which brings us to …



LIGHTNING in Jupiter's atmosphere spotlights thunderstorms containing water, although how much water exists there remains an open question. Here, sunlight reflected from Jupiter's innermost large moon, Io, illuminates the jovian cloud tops. NASA/JPL

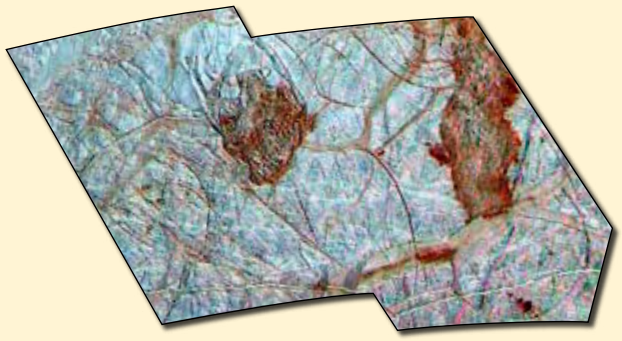
3 Where did the planets get their atmospheres and oceans?

As the largest unadulterated store of material left over from the solar system's birth, Jupiter can shed light on how volatile substances were distributed some 4.5 billion years ago. Before the Galileo mission, scientists thought icy planetesimals trapped heavy elements early in the solar system's formation, carrying them into the hearts of developing gas giants. If true, the ratios of heavy elements present in Jupiter — and how they differ from the Sun's elemental makeup — would give the ingredients needed to understand how Jupiter's present form developed.

Rather than revealing different ratios between the Sun and Jupiter, however, Galileo showed the two objects have identical ratios of important heavy elements. The key difference: Jupiter has 3 times the quantity of these elements as the Sun. SwRI's Levison wonders why. "It's just not clear what this means, but it's a real problem. Sure, Jupiter has more silicon and carbon, but you might think it just ate a bunch of asteroids. The problem is that it's enriched in argon and other noble elements, too. How you get that, no one knows."

Perhaps Jupiter formed near the end of planetary accretion, when these gases were more abundant, suggests Levinson. Or maybe it formed way out where conditions were different, and then migrated in. "If it formed in about the place it is now, the solar nebula was colder than we think," he adds. Tracking down the reasons for Jupiter's enrichment will lead to an understanding of early events in solar system formation.

The answer also has meaning beyond Jupiter's realm. "All this is interesting and important for a couple of reasons," says Ingersoll. "First, where did Earth get its atmosphere and oceans? In other words, where did our volatiles come from? Early on, it was too warm to condense out water, so we probably got ours from comets. Did Jupiter? And second, what's the probability that Earth wouldn't survive the formation of the giants?" Some planetary-system formation models indicate earthlike worlds are extremely rare in systems where Jupiter-class planets form near their parent stars. Researchers believe understanding the relationship between the outer giant planets and inner terrestrial planets will yield keen insights into extrasolar planetary systems.



EUROPA'S ICY CRUST hides a vast underground ocean that contains as much water as all of Earth's oceans. A big question faces exobiologists: Could life have started on the Jupiter moon and, if so, is it still there? NASA/JPL

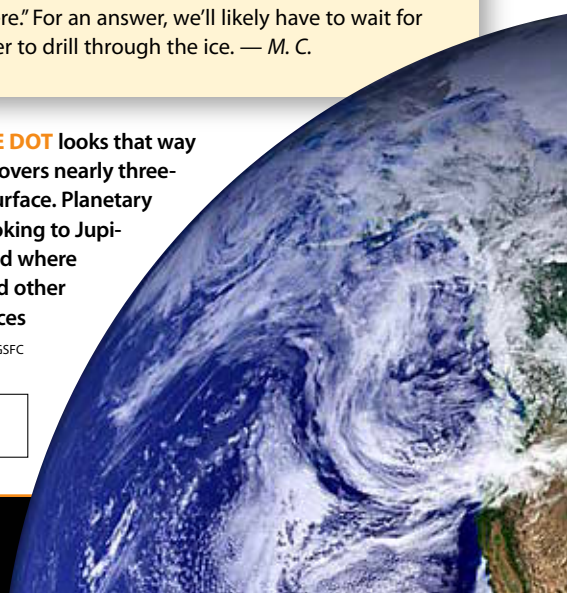
DOES EUROPA HARBOR LIFE?

Of all the mysteries surrounding Jupiter, perhaps the biggest literally surrounds the giant planet — in the form of its orbiting moon Europa. Ever since the Galileo orbiter discovered an ocean of liquid water lurking beneath the moon's icy crust, scientists have wondered whether Europa could harbor life and — more importantly — whether it does.

"That's the big question to me," asserts Rich Terrile of NASA's Jet Propulsion Laboratory. "Europa is the most exciting place for the study of life. If we find life on Mars, that's great, but the problem is that there's a lot of Mars on Earth." In fact, 50 million metric tons of martian material — the equivalent of one Great Pyramid of Giza — fall to Earth every billion years. "But Europa has been isolated from Earth life. Here are two environments absolutely separated."

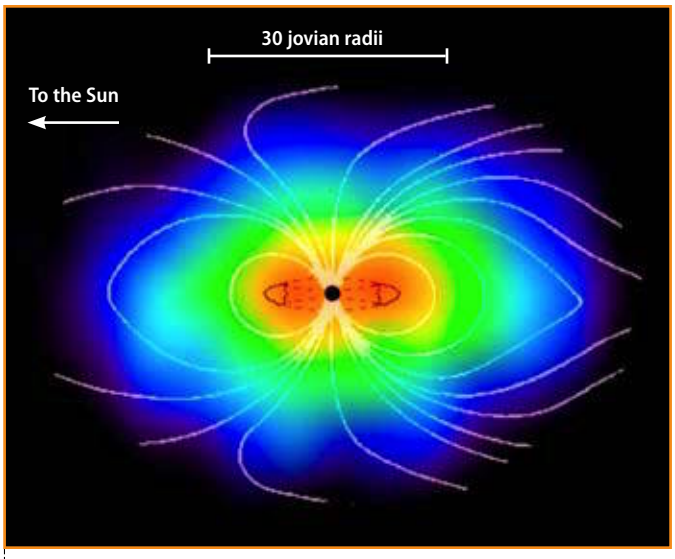
Europa's 60-mile-deep (100 kilometers) global ocean — caused by the same tidal friction that also conceivably could trigger submarine volcanoes there — gives exobiologists hope the small moon may host life. Europan habitats could resemble the deep-sea colonies of life surrounding terrestrial hydrothermal vents on Earth's ocean floor. Water can dissolve minerals, and it reacts in ways that seem necessary for life to flourish.

"The last time a new ocean was discovered was 400 years ago," says Terrile. "This [Europan] ocean has been cooking for billions of years. You throw in organic material — and there's a lot of it in the solar system — and it really makes you wonder what's down there." For an answer, we'll likely have to wait for a robotic explorer to drill through the ice. — *M. C.*

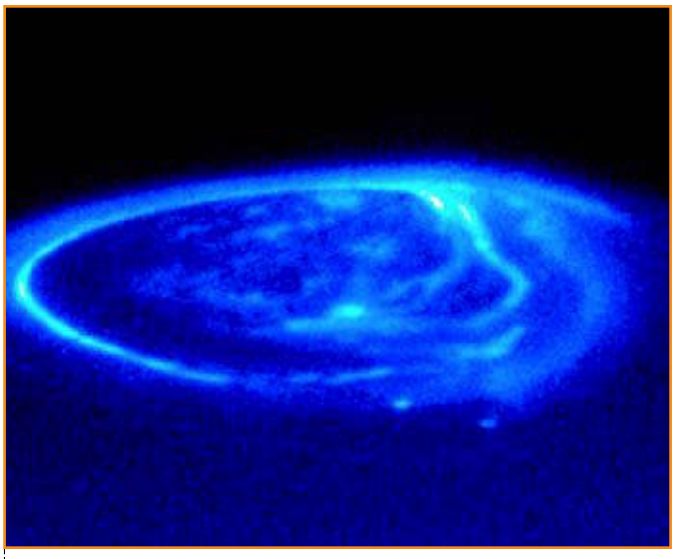


OUR PALE BLUE DOT looks that way because water covers nearly three-quarters of its surface. Planetary scientists are looking to Jupiter to understand where Earth's water and other volatile substances came from. NASA/GSFC

WEB EXTRA To listen to some of the sounds Jupiter makes as particles interact in the planet's magnetic field, visit www.Astronomy.com/toc.



JUPITER'S MAGNETOSPHERE stretches some 10 times the Sun's diameter, making it the largest structure in the solar system. The black circle shows Jupiter's size, and the curved lines represent the planet's magnetic-field lines. NASA/JPL/JHUAPL



AN ELECTRIC-BLUE AURORA dances above Jupiter's north pole. Interactions among the planet's atmosphere, magnetosphere, and moons drive the aurora, but a full understanding likely won't come until the Juno orbiter arrives. NASA/THE HUBBLE HERITAGE TEAM (AURA/STScI)

4 How does Jupiter's magnetic field work?

Jupiter has the most powerful and extensive magnetosphere of any planet in our solar system. Jupiter's magnetic field is 14 times stronger than Earth's and, if it were visible to the naked eye from our home planet, the energy field would span twice the diameter of the Full Moon. In reality, the field stretches roughly 10 million miles (16 million km) — some 10 times the Sun's diameter. This internal dynamo tips 11° from Jupiter's spin axis, and has been a conundrum for decades.

The Juno mission, currently slated for launch in August 2011, promises to unveil the magnetosphere's inner workings. "It's almost a fishing expedition," admits Ingersoll. "We don't know what we'll find until we get there. The details matter, and the best way to get at the details is to fly close to the poles."

Throughout Earth's history, the magnetic field has changed and shifted, reversing itself many times. Does Jupiter's field change in similar ways? "Figuring this out is bound to tell us a great deal about how planetary dynamos work," adds Ingersoll.

5 How are the magnetosphere and aurorae related?

Both Voyager spacecraft flew past Jupiter close to the planet's equatorial plane. Some 15 years later, Galileo entered an orbit around Jupiter near the equator as well. Mission planners chose these trajectories not only to get the best views of the planet's moons and rings, but also to avoid the harshest radiation environments. Consequently, all previous missions missed studying in detail Jupiter's poles, where charged particles generate the most powerful aurorae in the solar system.

Unlike earlier flybys and the Galileo orbiter, the Juno spacecraft will settle into a polar orbit. Its elliptical track will carry the orbiter from just 2,790 miles (4,500 kilometers) above the cloud tops at closest approach out to 1,775,000 miles (2,850,000 km).

This will allow Juno to dive through the planet's potent magnetosphere quickly, so it won't spend much time in the areas of heaviest radiation. This, in turn, will give scientists plenty of opportunity to scrutinize the regions where auroral activity is strongest. Juno's advanced suite of plasma physics instruments promises to revolutionize scientists' knowledge of Jupiter's aurorae.

A busy future?

Jovian exploration has just begun to whet our scientific appetites, says Terrile. "In science, one data point doesn't tell you much. Two points are great; you can draw a line between them and make your assumptions. But as my professor Jim Westfall once said: 'Don't ever get that third point. It will only give you hell.'"

It seems the line drawn between the data points before the Galileo mission has been outflanked by new revelations. The complexities of Jupiter assure future researchers a wild ride. A

BY MARTIN RATCLIFFE AND ALISTER LING

JANUARY 08

Morning meeting for Jupiter and Venus

This January is a great month for stargazing. Mars is near its best. Jupiter and Venus perform a spectacular morning conjunction. Comet 8P/Tuttle is on view early in the month. And the prolific Quadrantid meteor shower occurs with little lunar interference. Throw in the Moon's occultation of the Pleiades star cluster, and the only thing that could improve observing would be warmer temperatures. All in all, it's not a bad way to start off the year.

44 Watch Jupiter and Venus meet
53 See a flurry of meteors
53 Observe Hortensius' lava domes
54 When to view the planets
54 See Comet Tuttle
55 Ceres arcs through Cetus
55 View Saturn's moons

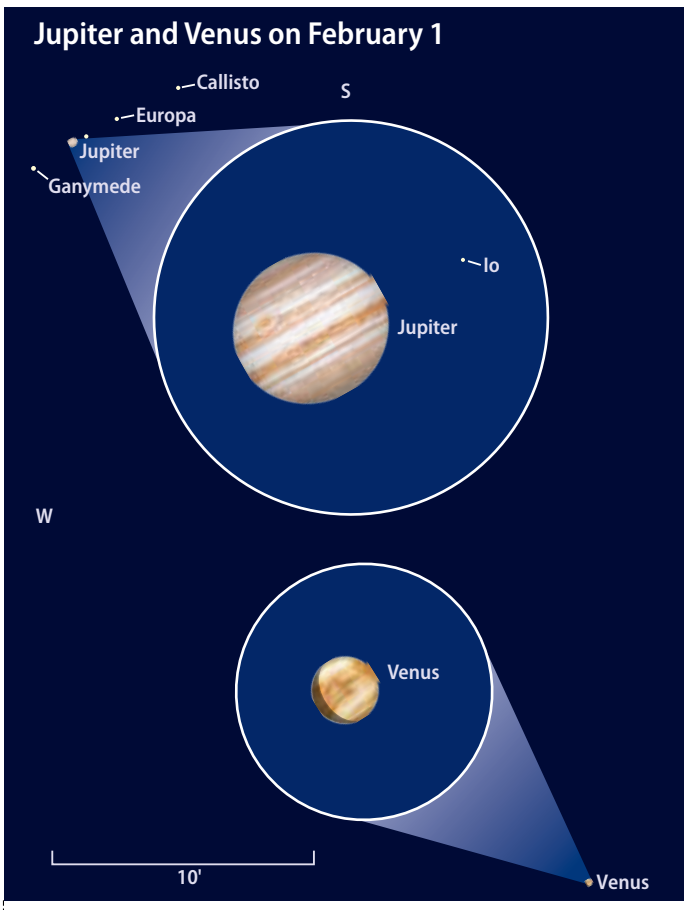
Visible to the naked eye
Visible with binoculars
Visible with a telescope

Our planetary tour begins with **Mercury**'s emergence into the evening sky. You may spot it first January 8, when it shines at magnitude –0.9. Through a telescope, Mercury will show a disk 90-percent illuminated because the planet has just rounded its orbit's far side.

A thumbnail crescent Moon joins Mercury January 9. The Moon, which is less than 36

— *Continued on page 53*

JUPITER JOINED VENUS (left) for an early morning rendezvous in November 2004. Here, the pair gleams over Bursa and Uludag, Turkey, before dawn. A similar sight awaits early risers throughout late January. TUNÇ TEZEL

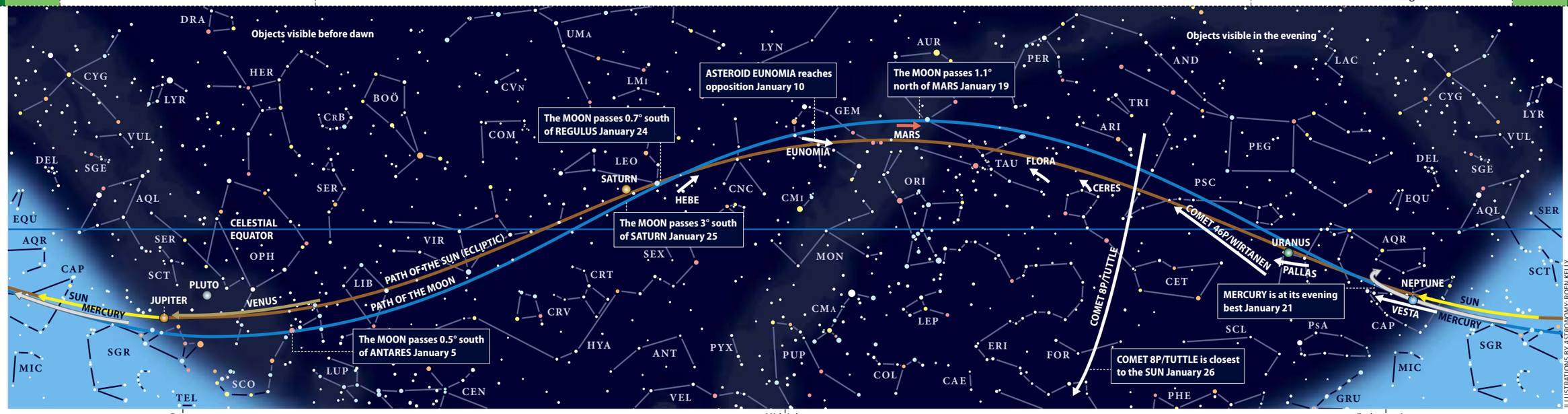


VENUS AND JUPITER make their closest approach to each other February 1. That morning, use a telescope and a low-power eyepiece to take in both planets — and all four of Jupiter's brightest moons as well. *ASTRONOMY*: ROEN KELLY

Planets this month

This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and colored dots show motions and locations of solar system objects during the month.

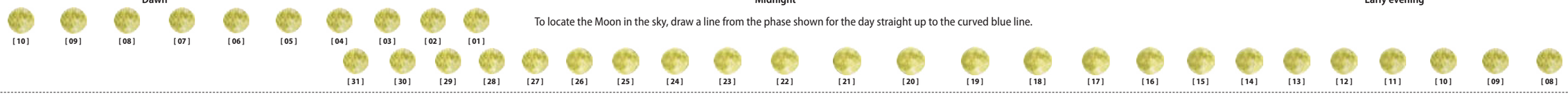
Astronomy magazine



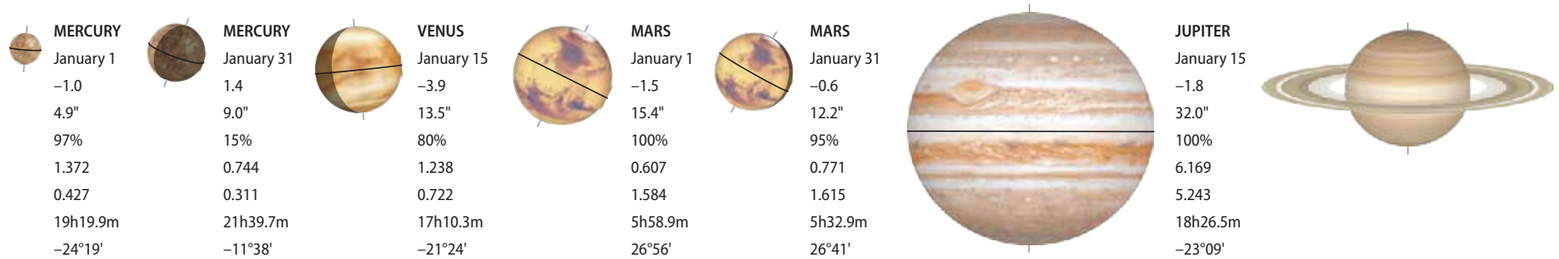
ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

Dawn — Midnight — Early evening

To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.

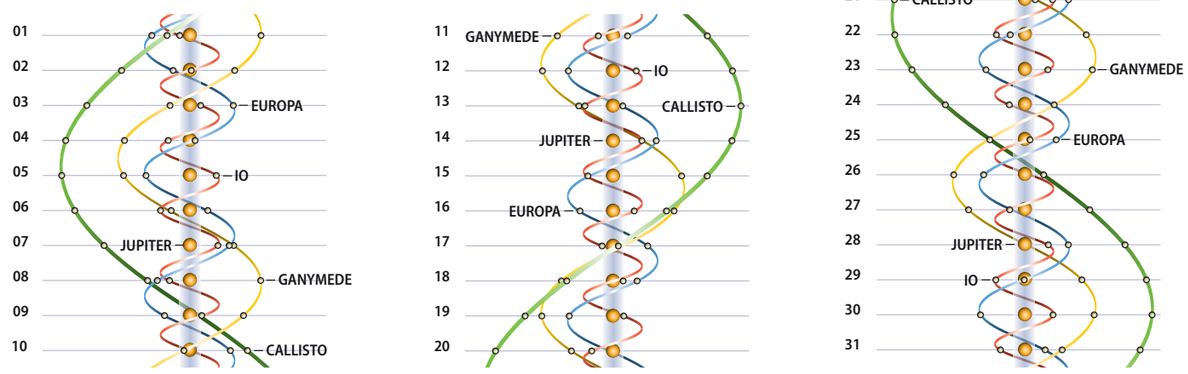


PLANETS	MERCURY	MERCURY	VENUS	MARS	MARS	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	January 1	January 31	January 15	January 1	January 31	January 15	January 15	January 15	January 15	January 15
Magnitude	–1.0	1.4	–3.9	–1.5	–0.6	–1.8	0.5	5.9	8.0	14.0
Angular size	4.9"	9.0"	13.5"	15.4"	12.2"	32.0"	19.5"	3.4"	2.2"	0.1"
Illumination	97%	15%	80%	100%	95%	100%	100%	100%	100%	100%
Distance (AU) from Earth	1.372	0.744	1.238	0.607	0.771	6.169	8.534	20.691	30.919	32.288
Distance (AU) from Sun	0.427	0.311	0.722	1.584	1.615	5.243	9.270	20.096	30.042	31.402
Right ascension (2000.0)	19h19.9m	21h39.7m	17h10.3m	5h58.9m	5h32.9m	18h26.5m	10h40.6m	23h08.7m	21h32.3m	17h58.0m
Declination (2000.0)	–24°19'	–11°38'	–21°24'	26°56'	26°41'	–23°09'	10°15'	–6°18'	–14°54'	–17°10'



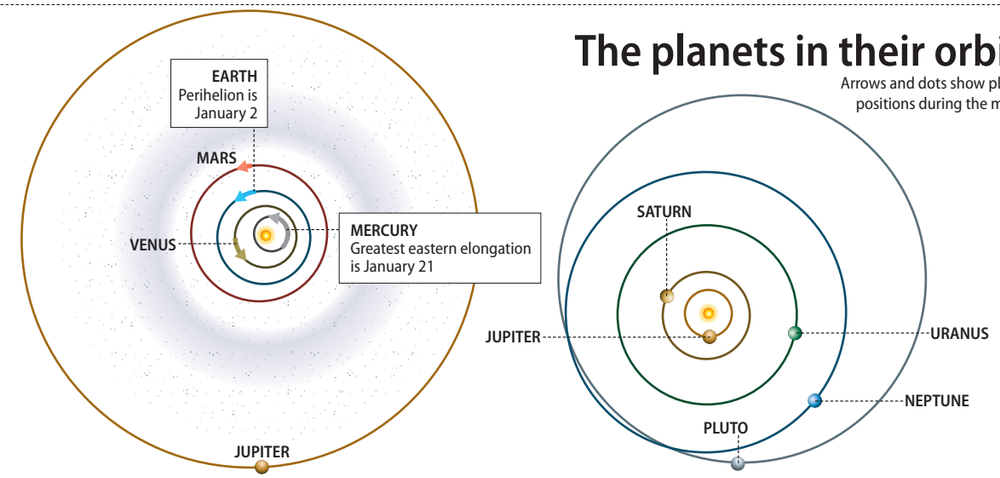
Jupiter's moons

Dots display positions of Galilean satellites at 7 A.M. EST on date shown. South is at top to match the view through a telescope.



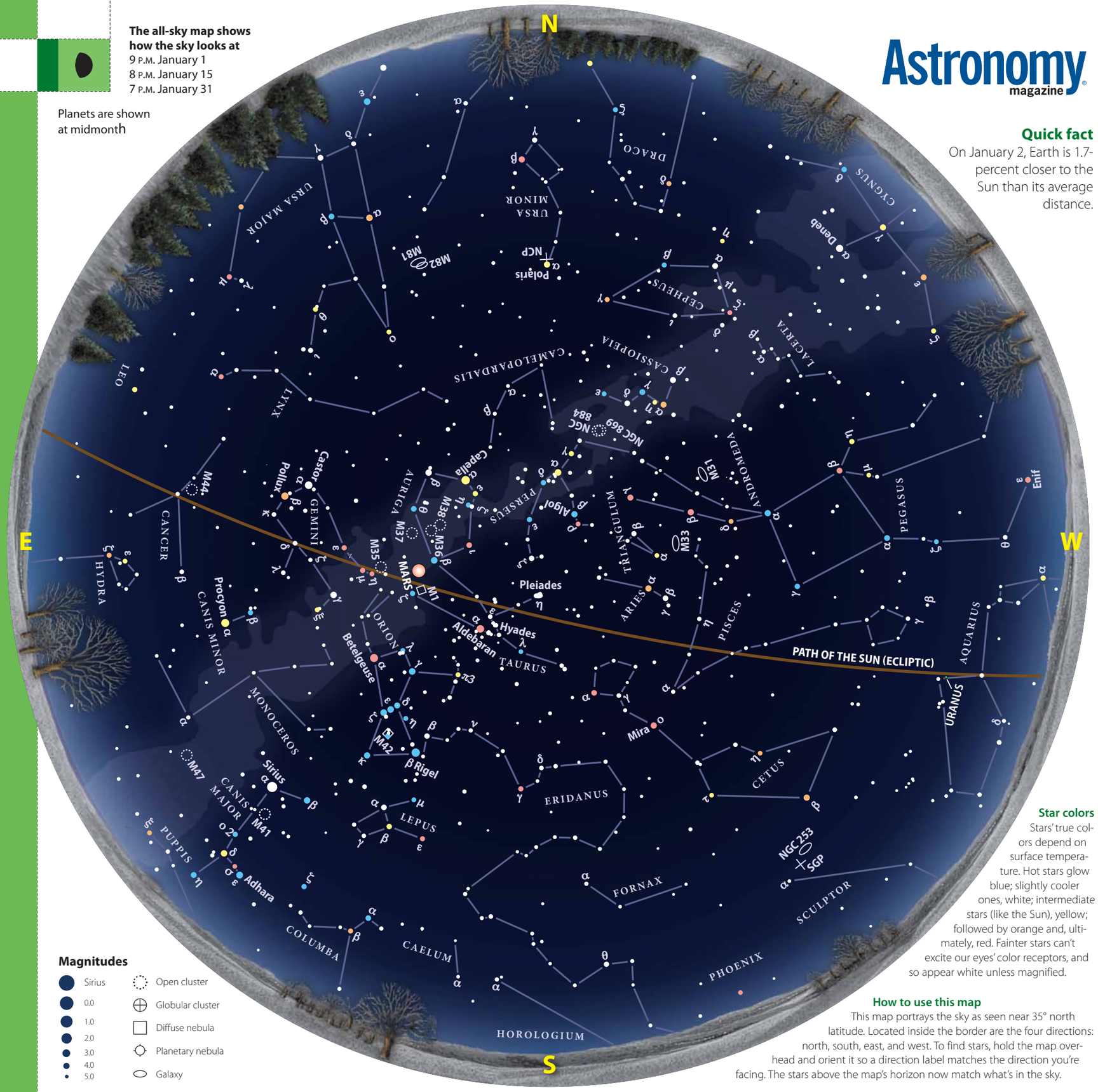
The planets in their orbits

Arrows and dots show planets' positions during the month.



The all-sky map shows how the sky looks at
9 P.M. January 1
8 P.M. January 15
7 P.M. January 31

Planets are shown at midmonth



Magnitudes

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0
- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

Star colors
Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

How to use this map
This map portrays the sky as seen near 35° north latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

Astronomy magazine

Quick fact
On January 2, Earth is 1.7-percent closer to the Sun than its average distance.

NOTABLE OBSERVING DATES: Mercury is at its best half an hour after sunset January 16–27. Look low in the southwest.

january 08

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
		[01]	[02]	[03]	[04]	[05]
[06]	[07]	[08]	[09]	[10]	[11]	[12]
[13]	[14]	[15]	[16]	[17]	[18]	[19]
[20]	[21]	[22]	[23]	[24]	[25]	[26]
[27]	[28]	[29]	[30]	[31]		

ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

02 Earth is at perihelion (91.4 million miles from the Sun), 7 P.M. EST

03 The Moon is at apogee (251,861 miles from Earth), 3:05 A.M. EST

04 Quadrantid meteor shower peaks

05 The Moon passes 7° south of Venus, 1 A.M. EST

The Moon passes 0.5° south of Antares, 5 A.M. EST

06 Venus passes 6° north of Antares, 9 P.M. EST

08 New Moon occurs at 6:37 A.M. EST

10 The Moon passes 0.4° south of Neptune, 8 P.M. EST

12 The Moon passes 3° north of Uranus, 8 P.M. EST

15 First Quarter Moon occurs at 2:46 P.M. EST

19 The Moon is at perigee (227,689 miles from Earth), 3:33 A.M. EST

The Moon passes 1.1° north of Mars, 7 P.M. EST

21 **Mercury is at greatest eastern elongation (19°), midnight EST**

22 Full Moon occurs at 8:35 A.M. EST

24 The Moon passes 0.7° south of Regulus, 10 A.M. EST

25 The Moon passes 3° south of Saturn, 1 A.M. EST

26 Comet 8P/Tuttle is closest to the Sun, midnight EST

28 Mercury is stationary, 2 A.M. EST

30 Last Quarter Moon occurs at 12:03 A.M. EST

The Moon is at apogee (251,365 miles from Earth), 11:25 P.M. EST

WEB EXTRA For definitions of terms, visit www.Astronomy.com/glossary.

— *Continued from page 44*

hours old then, hangs 6° above the southwestern horizon half an hour after sunset. In fact, spotting Mercury, at only 4° altitude, may be easier. Look for the pair in binoculars — Mercury appears as a bright star in a twilit sky, with a thin crescent Moon 3° above and to its left.

Mercury sets 80 minutes after the Sun January 15. The planet fades slightly to magnitude –0.8 and shows a 77-percent-lit disk; this shrinks to 53 percent a week later. On January 21, Mercury reaches its greatest angle east of the Sun (19°) and remains above the horizon 90 minutes after sunset.

On subsequent evenings, Mercury quickly loses altitude and drops back into the Sun's glare. The planet fades as it diminishes to a crescent. On January 25, Mercury glows at magnitude –0.4.

Mars reached opposition December 24, and the Red Planet remains a fine object throughout January. Mars dominates the night sky, standing high among the stars of Taurus the Bull. The planet glows at magnitude –1.5 as the month opens. When twilight ends, the Red Planet already is more than 30° above the eastern horizon.

Observers rave about Mars, and rightly so. Yet, as any telescopic observer will readily admit, the planet's disk is really small. On January 1, Mars spans just 15".

Make sure your scope's optics are well aligned — it's an observing necessity for Mars. View the planet with patience:

Martin Ratcliffe *is the former president of the International Planetarium Society.* **Alister Ling** *is a meteorologist for Environment Canada.*

METEORS FLY FROM A MISSING CONSTELLATION

The Quadrantid meteor shower peaks January 4 at 2:30 A.M. EST. This is one of the year's strongest showers, with an hourly rate of 120 meteors. The Moon remains out of the way until after 5 A.M., which makes this year's observing prospects look excellent. Observers farther north are better placed.

The radiant lies between Boötes, Draco, and the Big Dipper's handle. Astronomers first recognized the shower as annual in 1839. Back then, the meteors flew from Quadrans Muralis (Wall Quadrant), which gave the shower its name. Hercules, Boötes, and Draco now share the stars of this defunct constellation.

Plan to observe from 1 A.M. until dawn January 4. The radiant is low in the northwest as the shower peaks. Activity wanes as the radiant rises, but this is offset by seeing more meteors from a higher radiant.

A near-Earth asteroid named 2003 EH_1 is related to the Quadrantid meteor shower. This is the second meteor stream linked to an asteroid, after December's Geminids. Astronomers suspect the object is a defunct comet — a fitting source for a meteor shower from a defunct constellation.

THE QUADRANTID METEOR SHOWER peaks before dawn January 4. There will be little interference from the waning crescent Moon, so observers with clear skies should see a great display. *ASTRONOMY:* ROEN KELLY

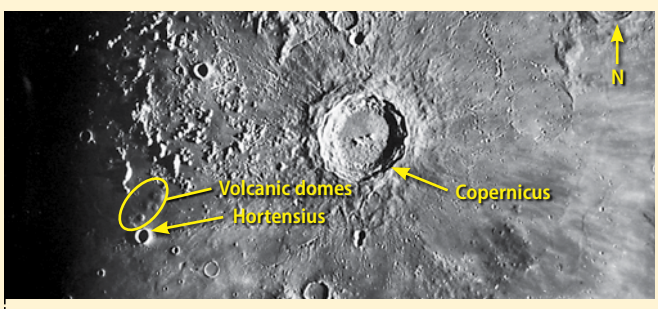
LAVA DOMES LURK NEAR COPERNICUS

The Moon's frozen face records the two types of events that shaped it — impacts and volcanism. In fact, the prominent impact crater Copernicus makes an easy starting point for a lunar trek that reveals both processes.

When Copernicus lies on the terminator, the line separating lunar day from lunar night, its high wall stands above the surrounding plain. The Sun rises on Copernicus January 16, but our journey begins the following night.

On Copernicus' sunward side, you'll see a surface with a splattered texture reminiscent of a rock dropped into a bowl of pudding. Secondary craters formed where rocks ejected in the main impact struck the surface. On the crater's opposite side, jumbled peaks jut above a lava-flooded terrain. Follow the peaks to the terminator, then track south to Hortensius.

To the north, six volcanic domes cast distinct shadows. The low Sun is critical to seeing these subtle features. If viewing conditions are superb, a 6- to 10-inch telescope might reveal the volcanic crater atop each of the domes' summits.



CONSOLIDATED LUNAR ATLAS (LPL/UA)

LOOK NORTH OF HORTENSIUS Crater January 17 and you'll spy a subtle cluster of ancient volcanic domes. Each is about 4 miles wide and roughly 1,000 feet high.

/// WHEN TO VIEW THE PLANETS

EVENING SKY	MIDNIGHT	MORNING SKY
Mars (east)	Mars (southwest)	Venus (southeast)
Uranus (southwest)	Saturn (southeast)	Jupiter (southeast)
		Saturn (west)

Allow your eye to become accustomed to the tiny orange disk. The fine detail is there, but visible only to those willing to wait for rare moments of atmospheric steadiness.

The Red Planet is visible all night long and arches almost overhead near local midnight. Mars gains a bright companion January 19, when the Moon lies just 3 lunar-diameters away.

Starting November 15, 2007, and continuing through January 30, Mars courses back along its retrograde loop. This takes Mars so far back into Taurus that the planet nearly hovers between the tips of the Bull's horns January 31. By then, Mars has faded to magnitude –0.6 and diminished to a 12"-wide disk. How soon can you detect the Red Planet's phase? By month's end, Mars will show a 95-percent-lit disk.

The Red Planet's rotation period closely matches Earth's — it's only 37 minutes longer. Observing over a 12-hour night, you'll be able to see half of Mars spin. Better yet, throughout the month, the difference in rotation periods gradually reveals Mars' other half. Looking from night to night in a single month, an observer can see the Red Planet's entire globe.

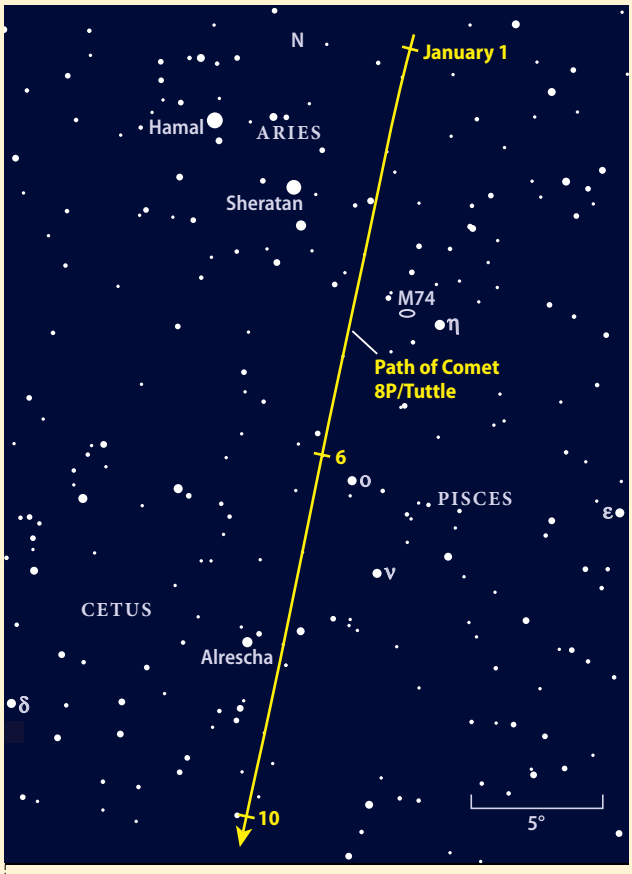
For example, the darkest feature on Mars, Syrtis Major, lies at the center of the planet's disk at 4 A.M. EST January 1; 4:37 A.M. January 2; and 5:14 A.M. January 3. Look for Sinus Meridiani centered on the disk January 25 at 11:00 P.M.; January 26 at 11:37 P.M.; and January 28 at 12:14 A.M.

Saturn greets late-night viewers early in January, when it rises in the east before 10 P.M. local time. The ringed planet lies more than 8° below Regulus as the stars of Leo rise. The planet brightens to magnitude 0.4 this month. Its rings are narrowing, and this year will be the last to view them well. In 2009, they'll be edge-on to us.

More of the planet itself is now on view. The boundary between Saturn's equatorial cloud belt and more temperate zones is the most prominent atmospheric feature. Notice how the planet's shadow darkens the rings' western side. Watch the shadow slowly diminish as Saturn approaches its February 24 opposition.

We can observe Saturn's satellites and their shadows crossing the disk now that the rings — and the plane of the moons' orbits — are near edge-on to us. The shadow of Titan, the planet's largest moon, is the easiest to see, and Titan's shadow begins transiting Saturn's disk later this year.

January's late sunrises let morning commuters see the two brightest planets close together. Jupiter edges nearer to Venus each day. This planetary *pas de deux* culminates February 1, when the two worlds lie



ASTRONOMY: RICK JOHNSON

COMET 8P/TUTTLE heads south. While visible to the unaided eye, the comet makes a great sight in binoculars or a telescope. The Moon interferes after January 10.

COMET 8P/TUTTLE DIVES TOWARD THE SUN

Any comet that becomes brighter than 6th magnitude is something special. From a dark sky, such comets are visible to the unaided eye and show plenty of structure in a telescope. On its 2008 return to the Sun, Comet 8P/Tuttle is just such a comet. Predictions suggest the comet will crest at magnitude 5.5.

The Moon-free observing window falls when 8P/Tuttle is at its best, from the last week in December to January 10. The highlight occurs December 30, when the dusty snowball lies only 1° from the Pinwheel Galaxy (M33). Binoculars will provide a delightful view of the pair, but only away from city lights. From suburbia, the galaxy will be invisible.

A telescope will show a bright dot in the center of the comet's glow. This is the false nucleus, so called because its shroud of sunlit dust blocks the comet's true surface from view. With luck, though, observers may catch sight of a thin dark line that extends from the coma's center — the icy nucleus' shadow, cast onto the tail's dust.

All too soon, the Moon's light intrudes. When it exits the scene, only observers near and south of the equator will be able to track the fading comet. For the rest of us, 8P/Tuttle will lie below the horizon.

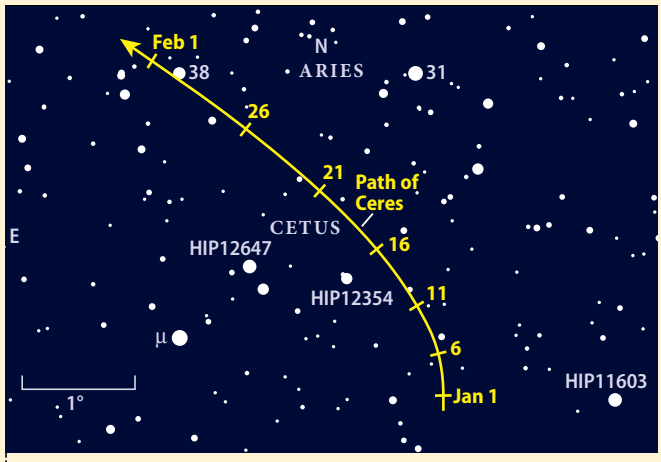
CERES CRUISES THROUGH CETUS

Following an asteroid in a small scope is a journey of the mind. It's not much of a challenge to find 8.3-magnitude 1 Ceres using a 60mm refractor. But when we set our eye on that dot of light in the eyepiece, our mind puts it in perspective.

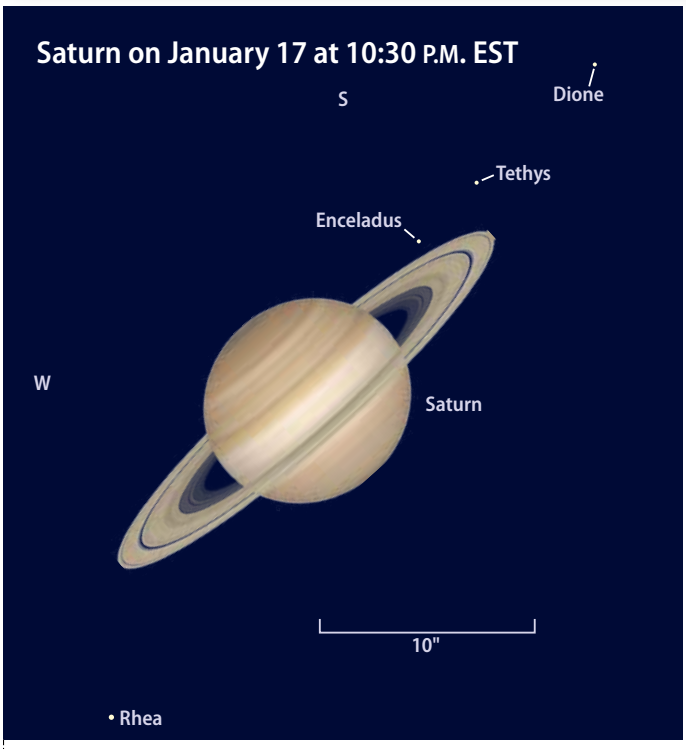
Spanning 580 miles, Ceres lies 215 million miles away, a little more than twice the average Earth-Sun distance. It's the biggest rock in the asteroid belt, by far. Ceres is almost twice the size of the runners-up, 4 Vesta or 2 Pallas. Ceres is so big, its self-gravity forces it into a round shape. For this reason, astronomers agreed to classify Ceres — along with Pluto and Eris — as dwarf planets.

In 7 years, NASA's Dawn spacecraft will provide the first close-up views of Ceres. Some scientists think the asteroid harbors water ice beneath a patina of rock and dust.

As twilight ends, look for the northern pair of stars that makes up the circlet of Cetus' tail, above Alpha (α) and Gamma (γ) Ceti. Ceres is easiest to find on the 29th, when it's only 4' south of 38 Arietis. But catch Ceres when you can: January weather is notoriously unreliable.



CERES, the largest asteroid, plies through Cetus and Aries this month. The 8.3-magnitude space rock is twice the size of the next-largest asteroids. Astronomers now classify Ceres as a dwarf planet. *ASTRONOMY:* RICK JOHNSON



SATURN'S THREE "ACTIVE" SATELLITES — Enceladus, Tethys, and Dione — align January 17, the same night the Moon occults the Pleiades. Can you spot these saturnian moons? *ASTRONOMY:* RICK JOHNSON

about one Moon-width apart. On New Year's Day, Venus rises 3 hours before the Sun and shines at magnitude –4.1 near the stars in Scorpius' head. Jupiter, however, is lost in the glow of morning twilight.

Venus traverses the constellation Ophiuchus from January 6 to 21. The planet is receding from Earth and lies 124 million miles away at month's end. A telescope shows the planet's phase growing from 77- to 84-percent lit, but Venus' diameter hovers between 13" and 14" all month. Watch for the nice predawn grouping of Venus and the crescent Moon January 5. Antares, the brightest star in Scorpius, lies 7° away.

By midmonth, Jupiter appears low in the southeast an hour before sunrise. The giant planet becomes an obvious sight a week later, when it rises into a darker sky.

On January 21, Venus and Jupiter stand 11° apart. During the next 12 days the gap between them diminishes, leading to their spectacular conjunction February 1. That morning, Jupiter lies 562 million miles away, or more than 4.5 times farther than Venus. Even so, a telescope will show Jupiter's 33" width is nearly 3 times the size of Venus' disk. The reason, of course, is that Jupiter, the solar system's largest planet, is 12 times Venus' size.

Venus passes about 2° from the Lagoon (M8) and less than 1° from the Trifid (M20) nebulae January 24 and 25. Jupiter stands less than 1° north of the globular cluster M22. The February 1 Venus-Jupiter conjunction occurs just 1.8° east of M22. The crescent Moon hovers 3° from Antares in the south.

With all the planetary action happening this month, it's easy to overlook the Moon. On January 17, as Mars glows brightly at the eastern end of Taurus, be sure to catch the waxing gibbous Moon as it closes on the Pleiades star cluster (M45).

By midnight, the Moon will lie much closer to M45. In the 2 hours that follow, early on the morning of January 18, the Moon's dark limb will edge ever closer to the cluster. Eventually, the Moon will cover up (occult) some of the Pleiades' stars.

The brightest star occulted will be 18 Tauri, which shines at magnitude 5.7. As a result, this event will be a challenge to observe in binoculars. But large telescopes (with apertures greater then 10 inches) will show the Moon blotting out many fainter stars. Times vary with your location, so check the International Occultation Timing Association's web site (www.lunar-occultations.com) for local details.

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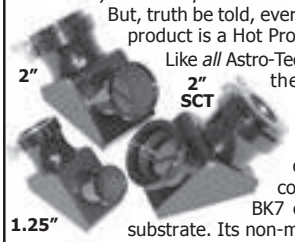
The **Astro-Tech** 1.25" *dielectric* star diagonal is a *Sky & Telescope Hot Product for 2007.* But, truth be told, every Astro-Tech product is a Hot Product!



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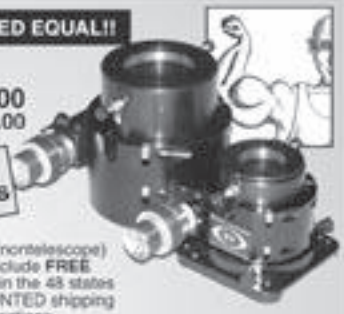

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Edward B. Burger is Professor of Mathematics in the Department of Mathematics and Statistics at Williams College. He earned a B.A. with distinction in Mathematics from Connecticut College (summa cum laude) and his Ph.D. in Mathematics from The University of Texas at Austin. He is the recipient of numerous honors, including the prestigious Chauvenet Prize presented by the Mathematical Association of America, and a variety of teaching awards.

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Archimedes calculated pi, or the ratio of the circumference of a circle to its diameter, as 3.1418.

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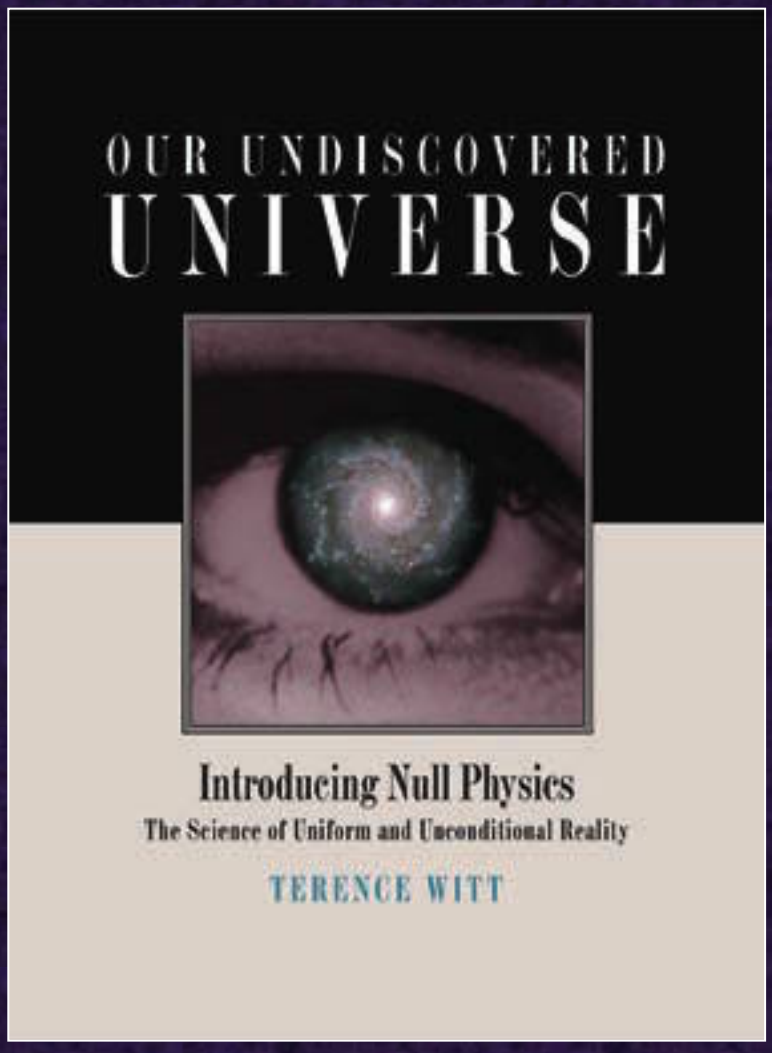

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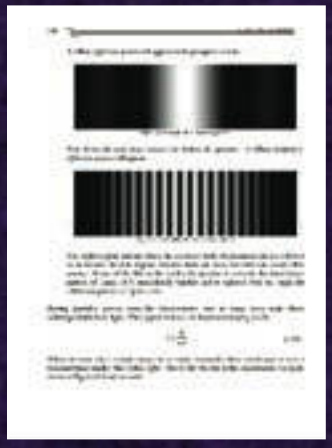

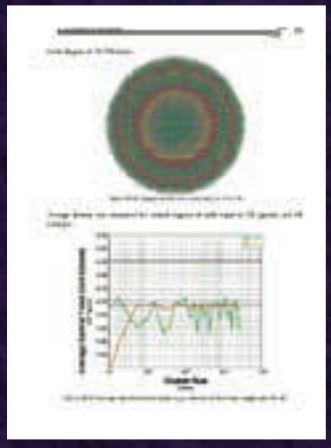

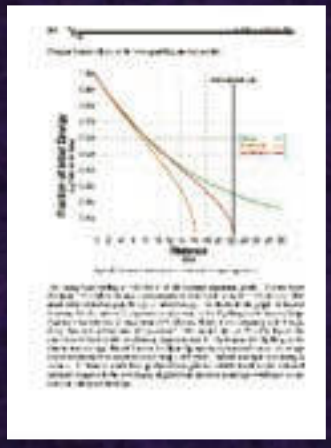

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Earth impacts at a glance

Asteroids and comets have slammed into our planet innumerable times. Here's where they've hit. /// BY FRANCIS REDDY

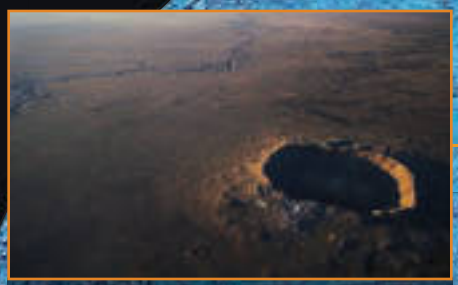
Impact cratering is the solar system's dominant geological process. But you couldn't know that if you studied only Earth's changing surface.

On land, erosion wears down the obvious signs of a strike, such as crater rims and central peaks. Water covers 71 percent of our world. In oceans and lakes, definitive evidence of an impact comes only from cores drilled deep into sediments.

Microscopic rock features let geologists identify asteroid and comet impacts. These include crystals deformed into narrow planes and minerals transformed into structures that require extreme temperatures and pressures, such as graphite turned into diamond.

No one knows how often Earth has been hit in its 4.6-billion-year history. The largest strikes came fast and furious 4 billion years ago, during the so-called Late Heavy Bombardment. Today, impacts big enough to make a hole the size of Arizona's Meteor Crater may occur every 50,000 years or so. An asteroid may blast out a 12-mile-wide (20 km) crater every million years.

This map plots 179 sites geologists confirm as impact locations, plus another 111 considered probable impact sites. Hundreds of additional candidate impact locales await more definitive study. NASA EARTH OBSERVATORY/FRANCIS REDDY/*ASTRONOMY*: JAY SMITH



METEOR CRATER is a modest but well-preserved structure in northern Arizona's Colorado Plateau. An iron meteorite blasted this three-quarter-mile-wide (1.2 km) bowl 49,000 years ago. PETER L. KRESAN

THE CHICXULUB IMPACT 65 million years ago helped destroy dinosaurs. The limestone sediments of Mexico's Yucatán peninsula preferentially erode near the buried crater's rim. It was an arc of sinkholes (cenotes) that indicated the structure's presence. An eroded limestone trough less than 15 feet (5 meters) deep formed directly above the rim. NASA/JPL

EARTH'S NEWEST CRATER formed in Carnacas, Peru, September 15, 2007. Witnesses saw the meteorite's fiery fall near noon, local time. Groundwater gradually filled much of the 45-foot-wide (13.8 meters) crater. INGEMMET

CORES DRILLED by the Antarctic research vessel USNS *Eltanin* revealed a 2.5 million-year-old impact near the Freeden Seamounts. No crater is known, but the ellipse's central portion is the world's most meteorite-rich site. A dot marks the sample taken closest to the impact's center.

Confirmed impact site
Probable impact site

Astronomy magazine

CLEARWATER LAKES formed when a pair of asteroids slammed into Quebec 290 million years ago. Clearwater Lake West (left), the larger of the pair, is 22 miles (36 kilometers) across. NASA

LAKE MANICOUAGAN in northern Quebec surrounds the 44-mile-wide (70 km) crater's central uplift. This impact struck some 212 million years ago. NASA/USGS

THE TUNGUSKA EXPLOSION of June 30, 1908, is the most significant impact event in the past century, but it felled and charred trees without leaving a crater. The asteroid exploded miles above Russia's Irkutsk province with the force of 15 megatons of TNT. SMITHSONIAN INSTITUTION

THE 2.4-BILLION-YEAR-OLD Suavjarvi structure in Karelia, Russia, is the world's oldest confirmed crater. The feature spans 10 miles (16 km) across.

SIKHOTE-ALIN is the youngest confirmed crater group. The iron meteorite fell on Russia's Primorsky Krai province at 10:38 A.M. local time February 12, 1947. The rock, which broke apart as it descended, gouged out more than 120 small craters.

ARKENU 1 AND 2 formed in a double impact. The Libyan craters are 6.2 and 4.3 miles wide (10 km and 6.8 km) and estimated to be less than 140 million years old. CARLOS ROBERTO DE SOUZA FILHO/EARTH IMPACT DATABASE, 2007

THE VREDEFORT STRUCTURE in South Africa spans 186 miles (300 km) — the largest confirmed impact crater on Earth. It's also the second oldest (1.87 billion years). CARLOS ROBERTO DE SOUZA FILHO/EARTH IMPACT DATABASE, 2007

AOROUNGA CRATER spans 8 miles (13 km) in northern Chad. An asteroid or comet struck this spot more than 300 million years ago. Originally buried in sediments, erosion has partially revealed Aorounga. NASA/JPL

THE CIRCULAR RING of hills at Australia's Gosses Bluff Crater spans 3 miles (4.8 km). This marks the central uplift of the heavily eroded, 15-mile-wide (22 km) structure. The Gosses Bluff impact occurred 142 million years ago. NASA/USGS

ASK ASTRO

This month:
- Where do comets live, and why do they have odd orbits?
- What effect would a nearby supernova explosion have on Earth?
- What happens when a black hole meets an antimatter star?
- What happens when a star 100 times the Sun's mass dies?

WEIRD ORBIT

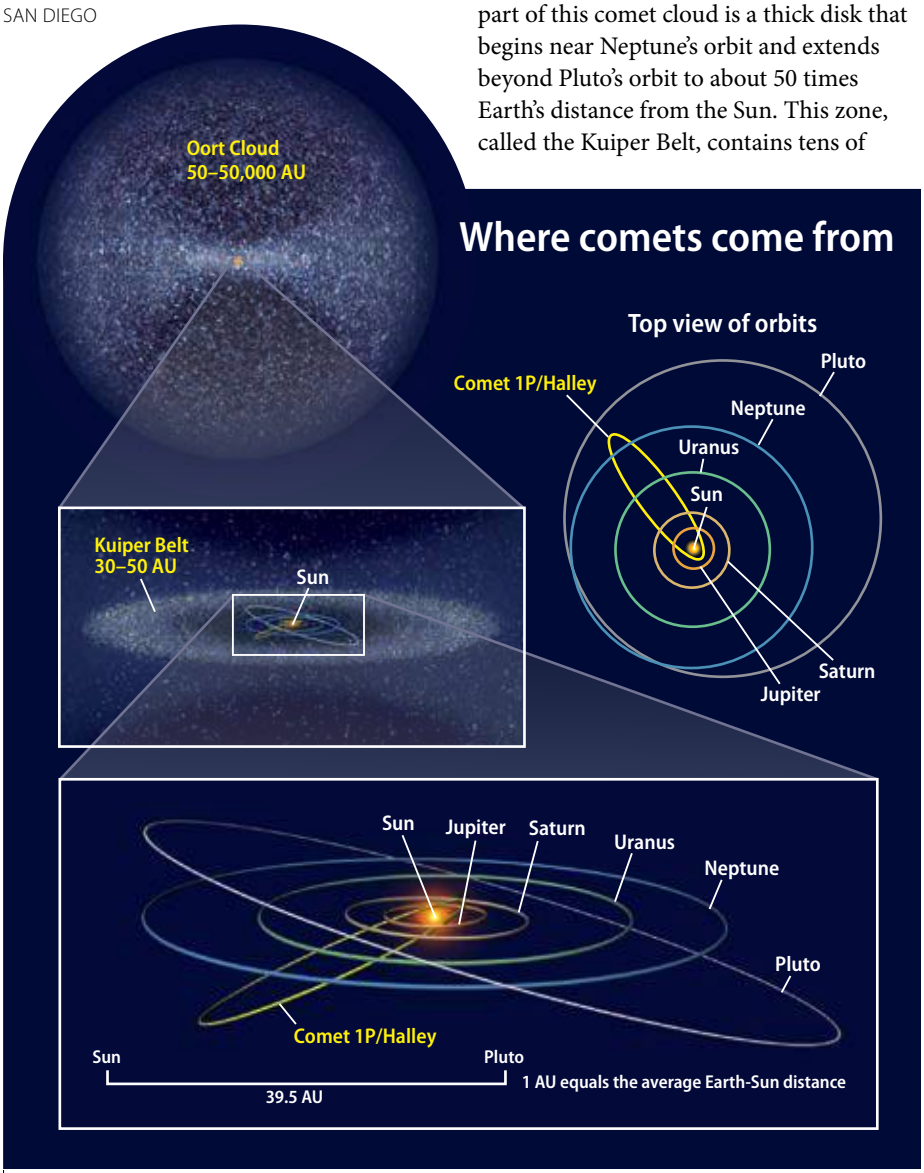
Q: Where do comets come from and why are their orbits so elongated? —JORGE ROBLES, SAN DIEGO

A: Astronomers think comets originate from two "cold storage" zones that surround the planetary system. The inner part of this comet cloud is a thick disk that begins near Neptune's orbit and extends beyond Pluto's orbit to about 50 times Earth's distance from the Sun. This zone, called the Kuiper Belt, contains tens of thousands of objects larger than 62 miles (100 kilometers) across.

A much larger and more diffuse component is called the Oort Cloud. It forms a Sun-centered, spherical shell extending from the outer Kuiper Belt to a light-year or more into space. Astronomers think it contains a trillion objects.

Feeble gravitational disturbances from passing stars and interstellar gas clouds remove enough orbital energy from Oort Cloud comets that they begin their million-year-long fall toward the Sun. These long-period comets may arrive from any direction, with their highly elongated orbits randomly oriented to the paths of the planets.

— **FRANCIS REDDY,** SENIOR EDITOR



COMETS MAY ORIGINATE from two "cold storage" zones surrounding our solar system: the Kuiper Belt and the Oort Cloud. Interlopers, such as interstellar gas clouds and close-venturing stars, create gravitational disturbances that can nudge objects within these zones into orbits that take them closer to the Sun. *ASTRONOMY:* ROEN KELLY

STAR COLLAPSE

Q: How would a supernova explosion near our solar system affect Earth? — DAVID DEROO, SILVER SPRING, MARYLAND

A: A supernova explosion might affect Earth in several ways. A blast of ultraviolet light from the explosion's shock wave would hit the exploding star's surface. The expanding gas releases deadly gamma rays from radioactive decay. **Cosmic rays accelerated in the remnant can destroy Earth's fragile ozone layer and allow the Sun's ultraviolet rays to fry the surface.**

The blast wave might also directly affect Earth, but it's more likely it will perturb the Sun's magnetopause (the boundary of the solar wind that holds off the interstellar medium). This would allow galactic cosmic rays to penetrate Earth's atmosphere and destroy any remaining ozone.

The magnitude of each of these effects depends on what type of explosion occurs: white-dwarf thermonuclear explosion or

massive-star core collapse. The latter would emit neutrinos that could penetrate Earth from any direction and, in principle, cause cell damage. For a supernova explosion to damage Earth's ozone layer, the explosion has to be closer than 100 light-years, maybe quite a bit closer. Such nearby events are rare, and no nearby star now could possibly do us harm.

A nearby supernova emitting a powerful gamma-ray burst (GRB) could also affect the ozone layer. These narrow jets of gamma-ray energy could do the job from a great distance — thousands of light-years. Fortunately, GRBs are rare and would have to point directly at Earth to harm us.

— **CRAIG WHEELER,** UNIVERSITY OF TEXAS AT AUSTIN

HEAVY MEETING

Q: What would happen if a black hole met a 1-solar-mass star made of antimatter?

— **DENNIS BROWN,** FORT WORTH, TEXAS

A: The antimatter star would meet the same fate as a matter star. It would spiral into the event horizon of the black hole and get ripped apart by tidal forces. To understand why, consider the phrase coined by astrophysicist John Weeler: "A black hole has no hair." Wheeler tells us a black hole's contents are not primarily matter.

IN THE KNOW

SUPERNOVA
The cataclysmic explosion of a star that can briefly shine as brightly as about 1 billion suns.

EVENT HORIZON
The boundary around a black hole from which, once crossed, light or matter cannot escape.

WHITE DWARF
The dense, collapsed, Earth-sized remnant of an intermediate-mass star like the Sun.

BARYON
Elementary particles such as protons and neutrons composed of three quarks.

DOOMED STAR **Eta Carinae sheds copious amounts of mass as it nears the end of its life. How much mass it loses determines whether it will eventually explode and leave behind a black hole or a neutron star.** NASA/ESA/N. SMITH (UNIV. OF CALIFORNIA, BERKELEY) ET AL./HUBBLE HERITAGE TEAM (STScI/AURA)

Physicists quantify this by assigning a "baryon number" to an object. An object's baryon number is its number of protons and neutrons minus its number of anti-protons and anti-neutrons. An object made of matter has a positive baryon number, while one made of antimatter has a negative baryon number. Wheeler's phrase is a folksy way of saying a black hole has a baryon number equal to zero.

Because a black hole isn't made of matter, it cannot tell the difference between a star made of matter and a star made of antimatter as either crosses the event horizon.

— **SCOTT DODELSON,** PARTICLE ASTROPHYSICS CENTER, FERMI NATIONAL ACCELERATOR LABORATORY, BATAVIA, ILLINOIS

STAR DEATH

Q: What will happen when the 100-plus-solar-mass star Eta Carinae dies? — JACOB BERTIN, WILLIAMSPORT, PENNSYLVANIA

A: The most massive stars may explode without leaving behind a black hole or neutron star. Some anomalously bright supernovae discovered recently, such as Supernova 2006gy (see "The king of supernovae," page 34), may be such "pair instability" supernovae.

Once a 100-plus-solar-mass star begins fusing carbon in its core, the gamma rays produced may collide and create pairs of electrons and positrons. **This process removes energy from the core. The star will collapse, and the core will undergo a runaway thermonuclear reaction, blowing the star apart.**

No one knows if Eta Carinae will end its life this way, and it may depend on how much mass the star can shed before it reaches the carbon-burning phase.

— **FRANCIS REDDY,** SENIOR EDITOR

COMING NEXT MONTH ...
Do black holes swallow neutrinos? Post your comments about this question online at www.astronomy.com/forums.

Send your questions via e-mail to: askastro@astronomy.com; or write to: Ask Astro, P. O. Box 1612, Waukesha, WI 53187. Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

Double your pleasure by spotting two types of deep-sky objects at the same time. /// **BY ALAN GOLDSTEIN**

Observe celestial odd couples

Amateur astronomers love picking off

targets with their telescopes, but they also like a bonus. When more than one type of object lies in your eyepiece, it's like an astronomical two-for-the-price-of-one sale. The following 10 "odd couples" are some of my favorites. To make moving from one pair to another easier, I listed them in order of right ascension.

All deep-sky odd couples appear by chance. Alignments exist between objects hundreds to millions of light-years apart. If you take several hundred planetary nebulae, stir in a thousand open and globular clusters, fold in a generous measure of bright stars and galaxies, shake well, and spread them out in the night sky, some of them will land on top of one another — their coordinates will be nearly identical.

M35 + NGC 2158

These two open clusters have little in common. M35 is visible to the naked eye under dark skies. At a distance of 2,800 light-years, it appears 28' in diameter. M35 is a rich cluster. It contains some 120 stars brighter than 13th magnitude and more than a thousand fainter stars.

NGC 2158 is much fainter, at magnitude 8.6, and compact, at 5' in diameter. This cluster contains more stars than M35 in an area about one-fifth in size.

DWARF GALAXY Leo I would appear faint anywhere in the sky. Seeing it is even tougher, however, because magnitude 1.3 Regulus lies only 20' away. CHRIS SCHUR

Other differences include distance — more than 11,500 light-years — and age. M35 is a young 150 million years old, while NGC 2158 is about 2 billion. The lives of the latter's blue stars ended a long time ago and only the less-luminous, more yellow stars remain. M35's loose structure contrasts with the concentrated NGC 2158.

M46 + NGC 2438

One of the best-known odd couples lies in Puppis. M46 is a rich open cluster visible to the unaided eye from a dark site. A small telescope reveals a 20'-wide mass of stars with magnitudes between 10 and 13.

Look for an out of focus "star" near the northern edge. A 4-inch or larger scope will show an 11th-magnitude ring about 1' in diameter — that's planetary nebula NGC 2438. It lies about 2,900 light-years distant; the cluster lies 5,400 light-years away.

NGC 2452 + NGC 2453

Less well-known is another open cluster/planetary nebula combination a bit more than 12° south of M46. NGC 2452 is a 12th

MOST OBSERVERS can spot M46 in Puppis with their unaided eyes. To spot planetary nebula NGC 2438 within the cluster, use a 4-inch or larger telescope. THOMAS V. DAVIS

OPEN CLUSTER M35 (left) in Gemini travels across the sky with a smaller, fainter companion cluster, NGC 2158. M35 shines at magnitude 5.1, making it a naked-eye sight from a dark location. BERNHARD HUBL

magnitude, ring-shaped planetary 0.5' across. NGC 2453 is a compact open cluster 5' in diameter glowing at magnitude 8.3.

Look for the nebula 6' south of the cluster. The cluster sits 19,000 light-years away, while the planetary is only 11,500 light-years distant.

Regulus + Leo I

The most challenging odd couple on this list is the dwarf spheroidal galaxy Leo I and one of the sky's brightest stars — Regulus (Alpha [α] Leonis). As dwarf galaxies go, this is one of the brighter ones, which isn't saying much. Leo I glows at roughly 10th magnitude, but the galaxy measures 12' by 9.8', so its surface brightness is even lower. It lies 20' due north of Regulus.

When observing Leo I, use sufficient magnification to get Regulus out of the

YOU'LL HAVE NO TROUBLE seeing this odd couple. Both the Owl Nebula (M97, lower right) and spiral galaxy M108 shine slightly brighter than 10th magnitude. LEE C. COOMBS

VIEWING THE HERCULES CLUSTER (M13) offers a bonus in spiral galaxy NGC 6207, only 28' to the northeast (lower right in this image). From a dark site, you'll spot this small galaxy through a 4-inch scope. MACE HOOLEY

CELESTIAL ODD COUPLES

DESIGNATION	TYPE	R.A.	DEC.	MAG.	SIZE
M35	OC	6h08.9m	24°20'	5.1	28'
NGC 2158	OC	6h07.5m	24°06'	8.6	5'
M46	OC	7h41.8m	–14°49'	6.1	27'
NGC 2438	PN	7h41.8m	–14°44'	11.0	66"
NGC 2452	PN	7h47.4m	–27°20'	12.0	30"
NGC 2453	OC	7h47.8m	–27°14'	8.3	5'
Leo I	G	10h08.4m	12°18'	10.2	12' by 9.8'
Regulus	Star	10h08.4m	11°58'	1.3	—
M97	PN	11h14.8m	55°01'	9.9	225"
M108	G	11h14.8m	55°01'	9.9	8.1' by 2.1'
M13	GC	16h41.7m	36°28'	5.8	16.6'
NGC 6207	G	16h43.1m	36°50'	11.4	3' by 1.1'
NGC 6520	OC	18h03.4m	–27°54'	7.6	6'
Barnard 86	DN	18h03.0m	–27°53'	—	5'
NGC 6712	G	18h53.1m	–8°42'	8.2	7.2'
IC 1295	PN	18h54.6m	–8°50'	12.7	86"
NGC 6723	G	18h59.6m	–36°38'	6.8	11'
NGC 6726-7/9	RN	19h01.7m	–36°53'	—	9' by 7'
NGC 6751	PN	19h05.9m	–6°00'	11.9	20'
V Aquilae	Star	19h04.3m	–5°41'	6.6–8.4	—

Key: R.A. = right ascension (2000.0); Dec. = declination (2000.0); Mag. = magnitude; G = galaxy; GC = globular cluster; OC = open cluster; PN = planetary nebula; RN = reflection nebula

EBONY AND IVORY aptly describe dark nebula Barnard 86 and open cluster NGC 6520. Filters don't improve the views of star clusters or nebulae, so don't use one on this pair. DANIEL C. GOOD

field of view. Regulus sits 78 light-years distant, while Leo I is more than 11,000 times farther — 900,000 light-years away.

The Owl Nebula + M108

One of the easiest odd couples to see consists of two Messier objects less than 1° apart. The Owl Nebula (M97) lies 48' south-southeast of spiral galaxy M108.

Both objects shine at magnitude 9.9. M97's pale disk spans 3.3'. It contrasts nicely with elongated M108, which measures 8.6' by 2.4'. Each shows mottled texture through an 8-inch scope. M97 lies about 1,500 light-years distant, while M108 sits some 45 million light-years away.

M13 + NGC 6207

The constellation Hercules is close enough to both the galactic plane and the Virgo cluster of galaxies to present a good mix of objects. It doesn't disappoint: It pairs its most famous object, globular cluster M13, with the magnitude 11.4 spiral galaxy NGC 6207, which lies 28' to the northeast.

M13's spectacular nature — magnitude 5.8 and 20' wide — makes observers forgetful of the surrounding area. Next time you look at M13, don't forget the galaxy "next door," but millions of light-years away.

NGC 6520 + Barnard 86

This celestial odd couple pairs a bright object with a dark one. NGC 6520 is a

Alan Goldstein *is a dedicated deep-sky observer and founder of the National Deep-Sky Observers Society.*

compact, magnitude 7.6 open cluster with 60 stars inside an area only 6' wide. About half the stars shine between 10th and 11th magnitudes. This object lies 5,000 light-years away and sits amid the galactic center's general glow.

Barnard 86 is a globule — a compact mass of dust — about 10 times closer to us than the cluster. The irregular blob stands in stark contrast from the cluster and the overall illumination from myriad stars. A 7th-magnitude orange star sits on the opposite side of the nebula from the cluster, making the field even more startling.

NGC 6712 + IC 1295

The small constellation Scutum contains another fine pair: NGC 6712 and IC 1295. You'll need at least an 8-inch telescope under a dark sky to pull in the latter object.

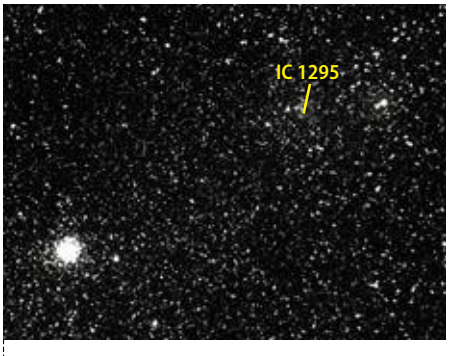
NGC 6712, a magnitude 8.2 globular cluster, measures 7' in diameter and lies 23,000 light-years away. IC 1295 is a ghostly planetary nebula 0.4° east-southeast of the cluster and a mere 3,600 light-years distant.

The planetary spans 86" and glows dimly at magnitude 12.7. Because of its low contrast, this is not an easy target. An OIII filter will help you see it.

NGC 6723 + NGC 6726-7/9

An unusual grouping of objects straddles the border between Corona Australis and Sagittarius. Globular cluster NGC 6723 lies near reflection nebula complex NGC 6726-7/9 and the large dark nebula Be 157.

Dark and reflection nebulae often combine and do not constitute an odd couple. Tossing a globular cluster into the mix, however, makes this region unusual. The nebular region also has the bright variable stars R and TY Coronae Australis.



GLOBULAR CLUSTER NGC 6712 and planetary nebula IC 1295 lie among a rich Milky Way star field. The cluster is easy to see; the planetary takes some effort. MARTIN C. GERMANO

THIS REGION in Sagittarius offers a lot. Reflection and dark nebulae abound as globular cluster NGC 6723 (top left) shines brightly. GERALD RHEMANN AND MICHAEL JÄGER

NGC 6726-7/9 is perhaps the closest star-forming region to Earth, located only 500 light-years away. NGC 6723 lies 60 times farther away, at 30,000 light-years. It shines at magnitude 6.8, which makes it one of the 20 brightest globulars, and it has a diameter of 11'. If this globular had a declination of 36° rather than –36°, it would have no doubt been a Messier object as well known as M2 or M15.

NGC 6751 + V Aquilae

Some celestial odd couples surprised me even before I observed them. Planetary nebula NGC 6751 is such an object.

A chart shows it 0.5° southeast of the magnitude 6.5 star V Aquilae. V is a carbon star, one of the reddest in the sky. This magnitude 11.9 planetary shows a circular disk about 20" in diameter. Its ghostly appearance at 6,500 light-years away is in stark contrast to the colorful star lying only 1,200 light-years away.

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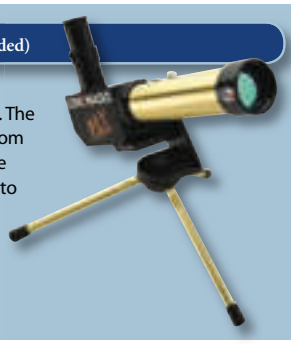

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PHOTO OF M3/ANDROMEDA GALAXY COURTESY OF JASON WARE

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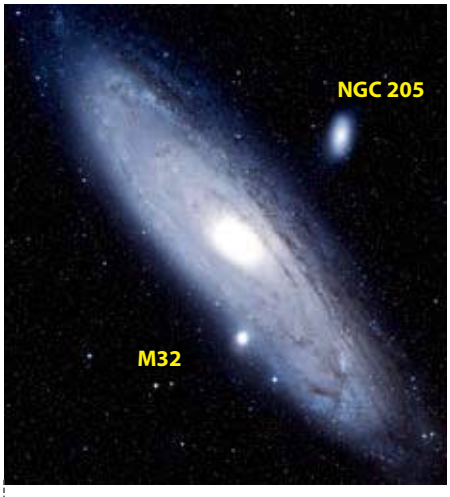
Colorizing Digitized Sky Survey images creates a new world of astronomical portraits. /// **BY CHARLES SHAHAR**

New pictures from old plates

Who doesn't enjoy the captivating images

returned to us by the Hubble Space Telescope (HST)? But did you know Hubble's raw images are snapped in shades of black and white? Red, green, and blue are added later to enhance an object's subtle detail or help visualize aspects not visible to the human eye. The resulting color images are stunning.

Few digital images in my collection possess Hubble's quality and sharpness, which should come as no surprise — few ground-based telescopes can match Hubble's clear view of the sky. However, not content to settle for images with less visual impact than Hubble's, I set out to create my own images using the Digitized Sky Survey (DSS).



THE ANDROMEDA GALAXY (M31) appears as a cotton-like oval in this colorized composite. Andromeda's two companion galaxies, M32 and NGC 205, are both bright dwarf ellipticals. Nearby M31 and the Milky Way both reside in a galaxy group known as the Local Group.

ALL SKY IMAGES BY CHARLES SHAHAR

The DSS is a collection of Schmidt photographic plates covering the entire sky. The plates date from various times during the past 57 years. Astronomers used the 48-inch Samuel Oschin Schmidt Telescope at Palomar Observatory on Palomar Mountain to run the Northern Hemisphere survey from 1950–1957, using blue- and red-sensitive plates. The U.K. Schmidt Telescope carried out a Southern Hemisphere sky survey beginning in the 1970s using similar plates.

The DSS2 consists of more recent survey plates taken with the same two telescopes. These plates are available in red, blue, and infrared wavelengths. In preparation for the second version of HST's *Guide Star Catalog*, the Space Telescope Science Institute (STScI) scanned these plates at high resolution.

Whereas the DSS images have a spatial resolution of 1.7" per pixel, the DSS2 images increase the resolution to 1.0" per pixel. When the Digitized Sky Survey project is complete, the collection will help produce a 2-billion-object catalog that includes multiple colors and objects' proper motions. The DSS2 scans have been compressed and written onto compact discs for distribution. Each color requires approximately 400 CDs.

You can download DSS images in either FITS or GIF format at several sites (archive.stsci.edu/cgi-bin/dss_form, ledas-www.star.le.ac.uk/DSSimage, cadcwww.dao.nrc.ca/cadcbin/getdss). Simply provide an object's coordinates or name, the field size, and the color selection. Some sites limit the field of view to a maximum of 60" — not wide enough for my taste. Other sites allow up to a 2° field of view that nicely fits objects such as the Andromeda Galaxy (M31), the Rosette Nebula (NGC 2237–9), and the Pelican Nebula (IC 5067–70).

PALOMAR OBSERVATORY

THE 48-INCH Samuel Oschin Telescope at Palomar Observatory captured images on red- and blue-sensitive photographic plates as part of the first Northern Hemisphere sky survey from 1950 to 1957.

Compose and combine

So, how did I turn black-and-white DSS2 images into full-color astroimages? First, I composed the image, which is not as easy as it sounds. I sometimes used a bright star to frame an object and create symmetry. Then, I downloaded low-quality GIF test images to tweak a composition before I extracted the larger FITS files.

Some DSS2 objects were overexposed on the original plates. I had to accept this fact because I had no control over the exposure

Charles Shahar *is an astrophotographer who lives in Montreal. Computer enhancement of digital images is his specialty.*

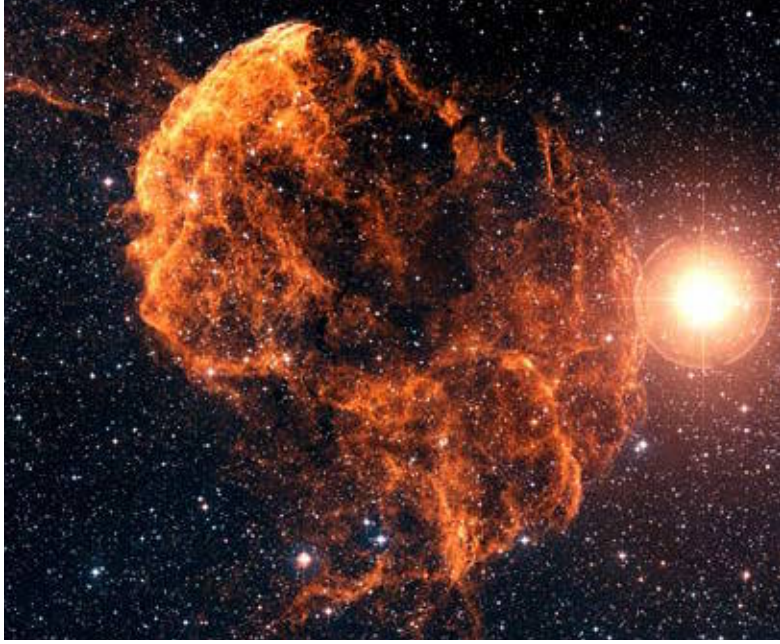
THE PELICAN NEBULA (IC 5067–70) in Cygnus shows a variety of striking features, including delicate wisps and a bright, backward S-shaped area of nebulosity (top center). The author started with unprocessed DSS images, added color using digital processing techniques, and combined images to create this stunning view of the Pelican.

times used. The Orion Nebula (M42), the Lagoon Nebula (M8), and the Eagle Nebula (M16) literally were burned into the image and unusable for my purposes. On the other hand, many of my favorite images, including the Pelican Nebula, the California Nebula (NGC 1499), and the Horsehead Nebula (Barnard 33), had optimal exposures. These images also were sufficient to capture a host of faint and lesser-known objects.

The DSS2 plates consist of monochrome images taken in different wavelengths. I had red and blue data, but the software I use requires a third channel, and the green channel was missing. I decided to create a false green channel by combining the red and blue images. I used *RegiStar* to align and combine the images. This software is accurate, quick, and free. The software rarely crashes, despite the fact I am combining large files (greater than 100 megabytes). *RegiStar* accurately aligns images for the best fit, even when small discrepancies occur between images.

First, I register the stars for the alignment process, using the blue image as the source file and the red as the reference image. I combine the red and blue images, using the default mode and assigning an equal weight to each channel. I save this combined photo as a false green-channel image.

Western part of the Veil Nebula (NGC 6960)



Jellyfish Nebula (IC 443)

Cone Nebula and Christmas Tree Cluster (NGC 2264)

Pinwheel Galaxy (M33)

Using *RegiStar*'s "Merged to RGB" function, I assign the three files to the individual color channels. The resulting tri-color composite is an image with an orange-brown tint. I save this file as a 16-bit TIFF and load it into *Photoshop* for further processing. If I simply combined the red and blue channels, the resulting image would be dominated by whatever color I chose to represent green, with fewer color variations than the tri-color version.

Your image-processing skills and creativity get a chance to shine when using *Photoshop*. First, load the image. It will appear washed out and lack contrast. Apply the "Auto Contrast" function to improve contrast. The image starts to look decent, but a wealth of detail remains hidden.

The "Curves" function allows you to adjust your image's brightness and color balance. I use this function to bring out faint structures in the image. It takes practice to apply Curves well. The trick is to shape the curve in such a way as to not burn the highlights, while accentuating the fainter structures. First, I do a curve adjustment in the

Flaming Star Nebula (IC 405)

Rosette Nebula (NGC 2237–9)

Cocoon Nebula (IC 5146)

The Pleiades (M45)

Emission Nebula IC 1848

red channel to reveal faint wisps of nebulosity. Then I use Curves in the other color channels to balance the image's overall hue.

Overcoming obstacles

One problem I've encountered is a grainy appearance from too aggressively pulling out tenuous nebulosity. Pixels are literally spread too thinly. In such cases, I use the "Adaptive" filter in *IRIS* image-processing freeware.

Simple "masking" techniques can enhance some areas of nebulosity that are over- or underexposed. Select an area using the "Lasso" tool in *Photoshop*, and then apply Curves to lower the contrast and pull out details. Or, conversely, apply a mask to enhance contrast and brightness.

Other features I use in *Photoshop* include "Hue/Saturation," "Color Balance," and "Levels." Choosing how muted or saturated an object appears, or the appropriate color balance, is an admittedly subjective process. I use my instincts as much as anything else. It may take several processing tries before I achieve an image with acceptable aesthetics.

The DSS2 images offer a unique opportunity for amateurs to process or manipulate images of remarkable quality and produce their own stunning results. The real fun is extracting faint, rarely imaged wisps of nebulosity.

DSS2 captured numerous extended nebulae in the northern sky. Armed with the Sharpless Catalog of nebulous, ionized hydrogen (HII) regions, you can spend hours extracting finely detailed filaments nestled amid clouds of Milky Way stars. What a nice way to spend cloudy nights!

Tele Vue's NP101is delivers ultra-sharp images. /// **BY JIM BURNELL**

A wide-field imager's dream scope

As CCD chips have grown in size, so too have the demands they place on telescopes. In 2004, Tele Vue Optics of Chester, New York, started work on a new design to address this demand. The Imaging System ("is") series provides a suitable image field for use with these chips.

I participated in the development of the "is" series as a prototype-tester. During evaluation, I imaged with each of the scopes using several different CCD cameras. I took images of dense star fields from my observatory, which I scrutinized intensely to assess the image quality.

The "is" series

Tele Vue's "is" series consists of the TV-60is (a 60mm f/6 APO doublet), the NP101is (a 101mm f/5.4 four-element Nagler-Petzval), the NP127is (a 127mm f/5.2 four-element Nagler-Petzval), and the TV102iis (a 102mm f/8.6 APO doublet). The NP101is is a modified version of the NP101, which traces its roots back to the original Tele Vue MPT designed by Al Nagler in 1980.

The Petzval telescope, whose lens is a four-element design with two widely-spaced groups, provides a flat field while still maintaining control over other aberrations. Designs using only front lenses, whether a doublet or a triplet, cannot accomplish this. The "is" series' short focal lengths and fast focal ratios make them the perfect telescopes for imaging wide fields. And all Tele Vue telescopes are handmade by a single optician in Tele Vue's factory.

The NP101is

The NP101is contains larger rear elements and a larger focuser than its predecessors to minimize vignetting (shadowing of the field that shows up as dark edges on images) on a focal plane up to 2" (51.9mm) across. Its focuser has an entrance aperture of 3" (76mm) and a full 2¼" (57mm) of clear aperture throughout its length.

Mechanically, Tele Vue's new focuser can support the heaviest CCD camera without flexing. The focuser has thick walls, and its drawtube rides inside a Teflon sleeve, which reduces friction. This sleeve doubles as a dust seal, keeping the inside of the focuser and the scope's rear elements clear of contaminants.

The focuser integrates a 6:1 reduction drive called the Focusmate, which allows the precise control required to focus a CCD camera on an f/5.4 system (or even f/4.3, when the optional 0.8x focal reducer is used). You can rotate the camera without changing focus thanks to a four-point collar built into the focuser's drawtube.

More than a scope

The "is" series has a comprehensive set of imaging accessories. Among them is a set of camera adapters, a 0.8x focal reducer, and a single-element large-field corrector (needed only for the largest CCD chips). Spacer rings go between the focal reducer or large-field corrector and the CCD chip to optimize performance.

TELE VUE'S NP101is, shown here set up for visual observing, operates at f/5.4. Attach SBIG's STL-11000M CCD camera, and you'll image a field of view 3.8° by 2.5° — 38 times larger than the Full Moon.

ASTRONOMY: WILLIAM ZUBACK

THIS IMAGE OF THE HEART NEBULA (IC 1805) in Cassiopeia shows delicate nebulosity and tack-sharp star images across the field of view. The author obtained this image through an NP101is with an SBIG STL-11000M CCD camera. This HαRGB image comprises 248 minutes of exposure time. JIM BURNELL

THE RED EMISSION NEBULA Sharpless 2–129 demonstrates the wide field and edge-sharpness of the NP101is. Color rendition also is excellent. The blue reflection nebula surrounding the star is Van den Bergh 140. TONY AND DAPHNE HALLAS

Tele Vue also makes a spacer that accommodates a 48mm filter. This allows imagers to insert a light-pollution reduction (LPR) filter in the image train. The filter proves useful for those who image under less than pristine skies.

The Focusmate is standard on all "is" scopes. Control of the Focusmate can be manual, remote (with the optional Focusmate Driver), or computer-controlled through a USB interface (with the optional FocusMaster). For repeatable precision focusing, the Fine Focus Indicator, a digital micrometer, is available with resolutions of 1 micron or 10 microns. Optional interface cables allow remote display of focus position on a computer via the FocusMaster or an RS-232 interface.

Tele Vue also offers a machined set of black-anodized mounting rings for the NP101is. Dovetail bases are available for the ring set in both 1.7-inch and 4-inch sizes to allow mounting the NP101is on most German equatorial mounts.

Jim Burnell *is an avid astroimager and coauthor of* The Handbook of Astronomical Image Processing *(Willmann-Bell, 2005).*

Appearance, fit, and finish

Tele Vue has a reputation for producing telescopes as beautiful to look at as they are to look through, and the NP101is is no exception. From the optical tube's pebble-grain, powder-coated ivory finish to the glass-bead-finished, black-anodized focuser, lens cell, and dew shield, the telescope exudes quality.

The felt-lined dew shield slid along the lens cell without slipping. It kept the lens dry on all but the most humid evenings.

The focuser worked smoothly in a variety of temperatures. It sports dual lock-screws, set 90° apart, which cause only the slightest image shift when tightened.

The Focusmate Driver also performed well. Unlike most electric focusers, you can disengage it by loosening a lock screw and rotating it. Combined with the Focusmate, it has a huge amount of torque and can move the drawtube even with the focuser lock moderately tight. It easily lifted 5 pounds (2.3 kg) of camera and cables, even with the telescope pointed straight up.

I have only one minor complaint: The front cover, which is heavy aluminum, can be difficult to thread onto the front cell, especially in the cold with gloves on. Tele Vue addressed this minor deficiency with the NP127is, which has a metal-rimmed Plexiglas cover with a convenient knob.

/// SPECIFICATIONS

TELE VUE NP101is

Lens: Nagler-Petzval, 4 elements in 2 groups
Aperture: 4 inches (101mm)
Focal length: 540mm
Focal ratio: f/5.4
Focuser: 6:1 reduction drive, 2.25" (57mm) of clear aperture
Included: Sliding, captive dew shield; 2" accessory adapter with clamp ring; custom-fitted hard-shell case.
Price: $3,985

Testing

For the past 2 years, I have imaged through the NP101is using a Starlight Xpress SXV-H9 CCD camera, which has a 9.98mm by 6.7mm CCD chip with 6.45 micron pixels, and an SBIG STL-11000M CCD camera, which has a 24.7mm by 36mm CCD chip with 9 micron pixels.

THE FOCUSMATE focuser comes with all Tele Vue "is" scopes. You can control the Focusmate manually, remotely (with the optional Focusmate Driver), or by computer (with the optional FocusMaster). *ASTRONOMY*: WILLIAM ZUBACK; BACKGROUND: JIM BURNELL

IMAGING ACCESSORIES for the NP101is currently total more than a dozen camera adapters, a 0.8x focal reducer and a large-field corrector lens. *ASTRONOMY:* JAMES FORBES

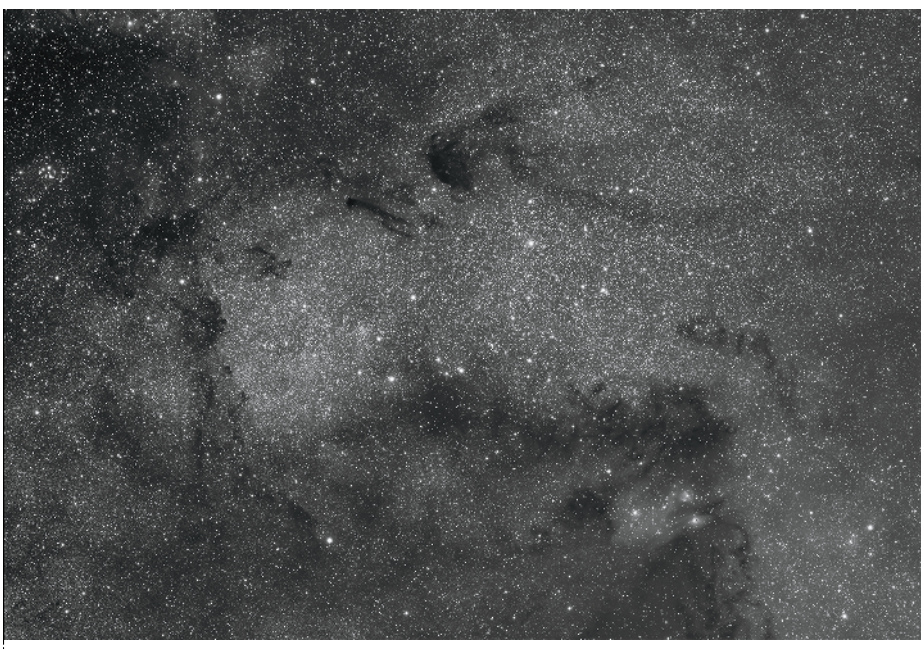
The small pixels on the SXV-H9 camera at the focus of the NP101is sample the sky at 2.44" per pixel. This camera is typical of amateur CCD cameras and provides a good test of image quality. I also used this camera to test the optional 0.8x focal reducer, which Tele Vue recommends for use only on CCD chips of APS-size (24mm by 16mm) and smaller.

Through the NP101is, SBIG's STL-11000M camera covers 3.8° by 2.5° of sky and serves as a demanding test for the NP101is' field flatness and its field illumination. The camera's weight — more than 4 pounds (1.8 kg) with cables and hoses attached — tested the focuser's ability to hold the camera without slipping or flexing during a multi-hour exposure.

Illumination and color

Imagers can enhance, or stretch, digital images to reveal details at low brightness levels. A telescope design that vignettes the CCD's field will create images with an uneven background, which becomes more obvious as the image is stretched. The NP101is provided a well-illuminated, uniform field that dropped off by less than 10 percent at the extreme corners.

Because the typical CCD chip detects a wider range of wavelengths than the human eye, deficiencies in color correction are obvious. The usual symptom is blue-bloat, where blue halos surround stars. The NP101is was free of chromatic aberration, as demonstrated by the celestial images accompanying this article.



A PERFECT TARGET for evaluating telescope image quality is the Sagittarius Star Cloud (M24). The imagers compared stars in the field's center and corners. In each region, star images are identical, a testimony to the flatness of the field. TONY AND DAPHNE HALLAS

ONE ACCESSORY astroimagers especially like is the Fine Focus Indicator, a digital micrometer with resolutions of 1 micron or 10 microns. You can also display focus position on a computer with optional interface cables. *ASTRONOMY:* WILLIAM ZUBACK

Visual observing

This telescope offers a side benefit for non-imagers: It's an even-better observing telescope. A large-chip CCD camera with small pixels requires telescope edge-field performance that far exceeds the performance required for visual observation.

The NP101is provided a visual observing experience unmatched by most similar-sized telescopes I have used. I routinely used this telescope for visual observations of Jupiter and Saturn with a 2.5mm Nagler Type 6 eyepiece (216x), and the images were stunning.

At the 2007 Winter Star Party in West Summerland Key, Florida, views of Saturn showed no color fringing. At 216x, the NP101is rendered both the Encke Division and the Crepe ring easily visible.

Tele Vue's NP101 has a great reputation for visual use, much coveted by observers. The NP101is continues in this tradition, adding imagers to the ranks of its fans. A

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BY GLENN CHAPLE

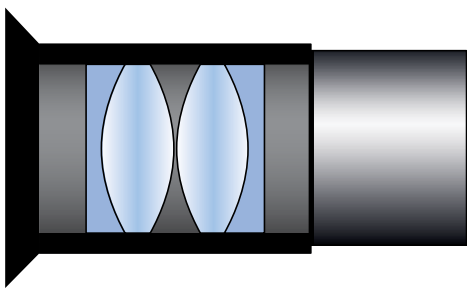
Eyepiece ABCs

Senior citizens often reminisce about how uncomplicated life was in the good old days. When it comes to amateur astronomy, they may have a point.

Consider eyepieces. Purchasing an eyepiece in the 1960s was easy, because you could choose from only a handful of basic designs. You could start out with a simple Ramsden or Huygens; or you might step up to a Kellner, or that crème de la crème of eyepieces, the orthoscopic. If you preferred an eye-pleasing wide-field view, you couldn't go wrong with an Erfle.

How times have changed! All but gone are the Ramsdens and Huygens. Plössl eyepieces have largely supplanted Kellners and orthoscopics. The trusty Erfle has made way for a mind-boggling array of computer-designed wide-field eyepieces. Here's a summary of the basic eyepiece designs available today.

Ramsden and Huygens: Once made in the 0.965-inch (24.5 millimeters) barrel size, Ramsden and Huygens eyepieces came with the low-quality 60mm refractors that glutted the market a few decades ago. Their images are inferior, especially in fast f/ratio telescopes, and their extremely narrow fields of view are guaranteed to give the observer a permanent case of tunnel vision.



PLÖSSL EYEPIECES are popular with many observers today. Plössls incorporate a pair of achromatic doublet lenses, a design that offers good image quality when used on a wide range of telescopes.
ASTRONOMY: ROEN KELLY

Kellner: The Kellner (a.k.a. achromatized Ramsden) and its cousin, the modified achromat, are similar to the Ramsden, except they contain a two-element achromat. The result is improved image quality and an acceptable 40° to 50° field of view.

The RKE is similar to the Kellner, except the achromat and single lens element are reversed. These are fine low-cost eyepieces for small-aperture scopes of any f/ratio, particularly at low to medium magnifications.

Ramsden and Huygens lenses commonly came with the low-quality 60mm refractors that glutted the market a few decades ago.

Orthoscopic: Replace the field lens of a Ramsden with a cemented triplet, and you have an orthoscopic eyepiece. A mainstay for lunar and planetary observers decades ago, the orthoscopic still has its adherents today. It delivers a 45° to 50° field and is especially useful for high-power observing applications.

Plössl: This design, comprising two achromatic doublets, first appeared in 1860 but didn't really catch on until the early 1980s. The Plössl offers a sharp image across a slightly wider field than the orthoscopic. Among the most popular and widely used eyepieces today, Plössls perform well with any f/ratio telescope.

Erfle: The grandfather of wide-field eyepieces, the Erfle consists of a trio of achromatic doublets or a pair of achromats separated by a double convex lens. It boasts a 60° to 70° field of view, although image sharpness falls off near the edge of the field. Its cousin the König is a better performer at high magnifications.

Wide-field revolution

Modern computer technology has given optical designers the freedom to create eyepieces that couldn't even be imagined decades ago. The result is an explosion of exotic wide-field designs, some with as many as eight elements.

The pinnacle of wide-field designs is the Nagler Ethos. Its jaw-dropping 100° field provides a "spacewalk" view of the universe. However, this and other top-of-the-line wide-field eyepieces cost as much as some small telescopes. Budget wide-field eyepieces are available, but they tend to suffer from distortions near the edge of the field when used with fast telescopes.

Using Barlows with low-power lenses: A Barlow isn't an eyepiece, but rather a booster lens that increases the magnifying power of any eyepiece. In the 1960s, Barlow lenses came with low-quality telescopes to provide the ridiculously high — and totally useless — magnifications their makers promised. As a result, Barlows got a bad reputation. Today, the savvy amateur astronomer combines a Barlow with a low-power eyepiece to increase magnification while retaining comfortable eye relief.

Questions, comments, or suggestions? E-mail me at gchaple@hotmail.com.

WEB EXTRA Learn more about the internal workings of different eyepieces at www.Astronomy.com/toc.

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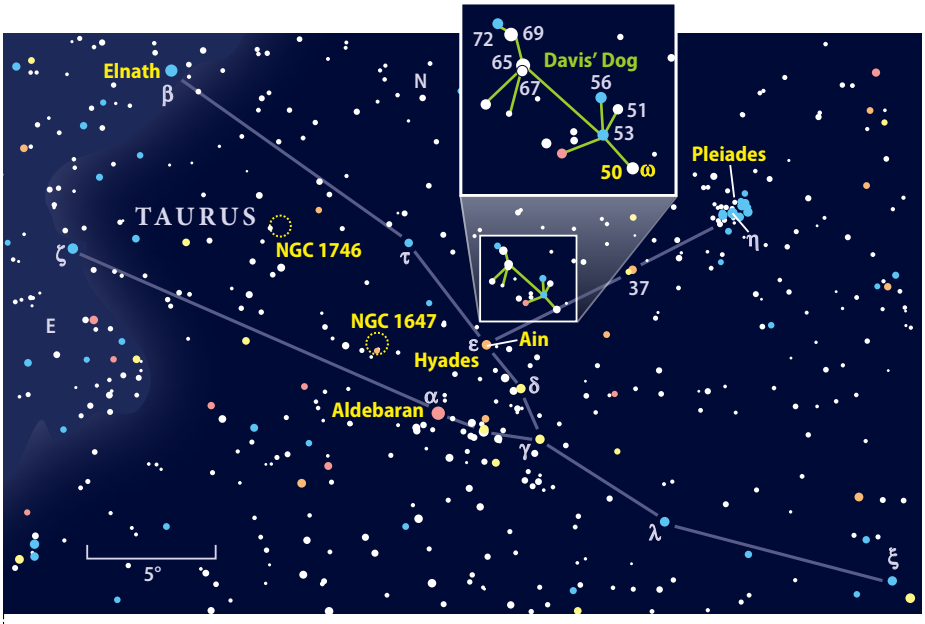
BY PHIL HARRINGTON

Tour two more clusters in Taurus

Quick, can you name a star cluster in the constellation Taurus the Bull? You probably said "the Pleiades," right? Now, name another open cluster in Taurus. "The Hyades," you say? Yes, the V-shaped face of Taurus is an open star cluster, save for Aldebaran, which only happens to lie along the same line of sight. How about another?



WHILE CRUISING TAURUS, you can view several challenging and beautiful open star clusters. And don't forget to check out the enchanting asterism "Davis' Dog." *ASTRONOMY:* ROEN KELLY

Although the Hyades and the Pleiades tend to steal the limelight, Taurus contains other excellent open clusters. This month, we're going to discover two of them through binoculars. Both lie between **Aldebaran** and **Elnath** (Beta [β] Tauri), the star in the tip of the Bull's western horn.

Our first target, **NGC 1647**, lies about one-quarter of the way from Aldebaran to Elnath. It's easy to see through 50mm binoculars. Begin at Aldebaran, and then extend the legs of the Hyades' V about half a binocular field (3°) to the northeast. Keep an eye out for three faint stars aligned east-to-west. The middle star, orange in color, lies on the southern edge of NGC 1647.

At first glance, NGC 1647 looks like a faint blur, but take a closer look and you should resolve at least a half dozen dim points of light. Those are the brightest of more than 200 suns in NGC 1647.

NGC 1746 lies about halfway between Aldebaran and Elnath. Like NGC 1647, it is a large open cluster, but it lacks the misty glow of NGC 1647's many faint stars. Instead, most binoculars show some 8 to 10 stars shining between magnitudes 5 and 9.

Lastly, return to Aldebaran and extend a line to the star **Ain** (Epsilon [ε] Tauri), which marks the western tip of the Hyades V. Continuing that line an equal distance farther northwest puts you right in the middle of a bright, but loose, gathering of 3rd- to 5th-magnitude stars.

From west to east, the group consists of Omega (ω), 51, 53, 56, 65, 67, 69, and 72 Tauri, along with a scattering of fainter stars. They all stand out clearly in 50mm binoculars. Take a close look: See any recognizable pattern among the stars?

The inventive eyes of John Davis in Amherst, Massachusetts, see a "cute little dog whose nose got caught in a pencil sharpener." Omega marks the tip of the dog's nose and 53 represents one of its eyes, while 51 and 56 Tauri lie at the tips of the dog's pointy ears. The arc of 65, 67, 69, and 72 Tauri outline the dog's tail; a pair of fainter triangular patterns to the south form its body and legs.

It's always fun to bump into star patterns that remind us of something here on Earth. Have you ever found an interesting asterism like that? If so, I'd love to hear about it. E-mail me at phil@philharrington.net with all the details and any comments and suggestions you might have for a column about your favorite asterisms.

Next month, we'll pay a midwinter visit to the sky's most famous brothers, Castor and Pollux, the colorful Gemini twins. Until then, remember our creed: Two eyes are better than one.

WEB EXTRA But wait, there's more! Learn how to find two more Taurus clusters at www.Astronomy.com/toc.

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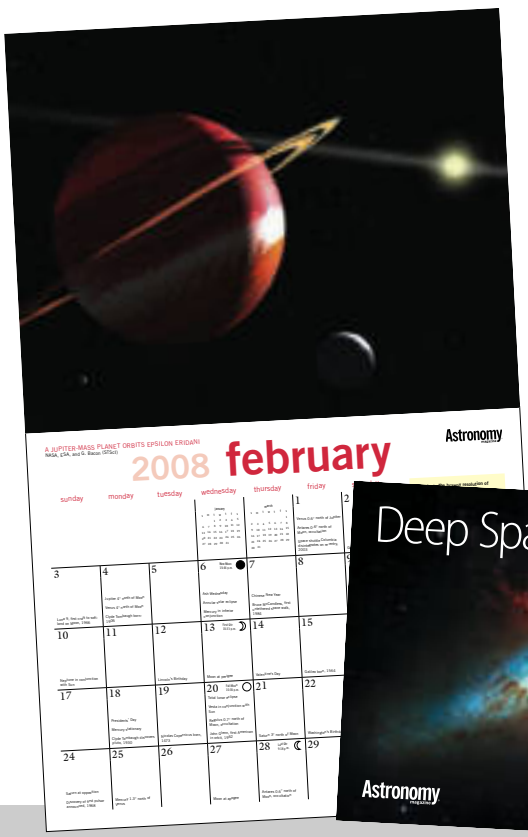

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Reader gallery

SPIRAL GALAXY M96 (20-inch RC Optical Systems Ritchey-Chrétien telescope at f/8, SBIG STL-11000 CCD camera, LRGB image with exposures of 4.5, 3, 2.5, and 3 hours, respectively) /// **ADAM BLOCK, TUCSON, ARIZONA**

GALACTIC VISTA

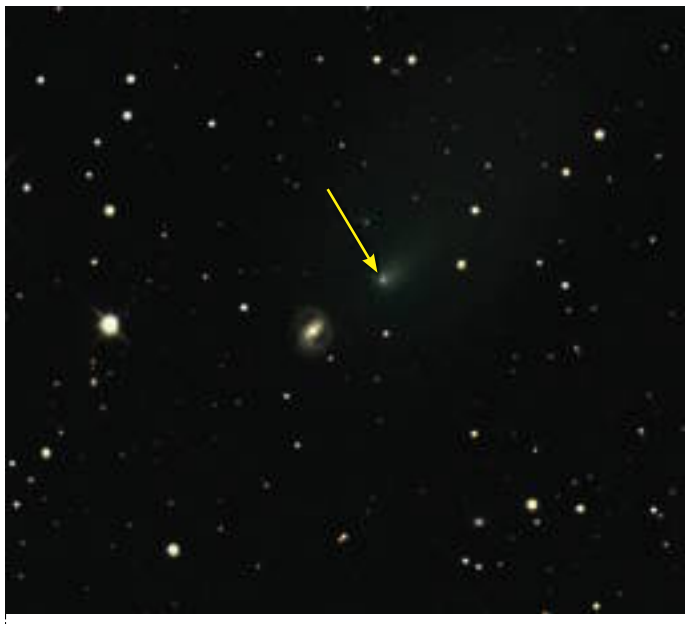
Grand spiral in Leo

Spiral galaxy M96 is the brightest member of a small group of galaxies that includes M95 and M105. The group lies 38 million light-years away. M96 spans 100,000 light-years, as large as the Milky Way. Note the many delicate dust lanes near the nucleus swirling toward the brilliant starlike core. This image also contains many smaller galaxies. Most intriguing is the edge-on galaxy to the upper-left of M96's core. Given its reddened color, this galaxy probably sits behind M96, and we view it through intervening clouds of gas and dust. If we assume this edge-on galaxy is roughly the same size as M96, it would be 3 to 4 times farther away.

Send your images to: *ASTRONOMY* Reader gallery, P. O. Box 1612, Waukesha, WI 53187. Please include the date and location of image and complete photo data: telescope, camera, and exposure information. To submit images electronically, visit www.contribute.kalmbach.com.

EMISSION NEBULA SHARPLESS 2–9 lies near magnitude 2.9 Sigma (σ) Scorpii. Reflected starlight accounts for the faint blue color. (6.4-inch Takahashi Epsilon 160 refractor at f/3.3, ST-10XME CCD camera, HαRGB image with exposures of 240, 30, 30, and 30 minutes, respectively) /// **DEAN SALMAN, TUCSON, ARIZONA**

COMET C/2006 VZ13 (LINEAR) passed near globular cluster M3 in Canes Venatici. The comet reached 8th magnitude at its brightest. (8-inch ASA Astrograph at f/2.75, Sigma 6303E CCD camera, LRGB image with exposures of 12, 1, 1, and 1 minutes, respectively, taken July 22, 2007, at 22h20m UT) /// **GERALD RHEMANN AND MICHAEL JÄGER, VIENNA, AUSTRIA**



WHEN COMET C/2007 E2 (LOVEJOY) (arrow) approached magnitude 14.8 barred spiral galaxy UGC 8467, both were faint objects. The comet glowed at magnitude 12.7. (12.5-inch homemade Newtonian reflector at f/5, SBIG ST-10XME CCD camera, LRGB image with exposures of 60, 20, 20, and 20 minutes, respectively, taken June 6, 2007, at 9 P.M. MDT) /// **CHRIS SCHUR, PAYSON, ARIZONA**

SPIRAL GALAXY M108 inclines to our view nearly edge-on. The galaxy shows no pronounced core or major star-forming regions but lots of dust. (12.5-inch Parallax Instruments Ritchey-Chrétien telescope at f/9, SBIG ST-10XE CCD camera, Astrodon filters, LRGB image with exposures of 60, 30, 30, and 30 minutes, respectively) /// **BOB AND JANICE FERA, FORESTHILL, CALIFORNIA**

NGC 2403 IN CAMELOPARDALIS is one of the brightest galaxies not on Messier's list of deep-sky objects. It shines at magnitude 8.4, measures 17.8' by 11', and lies 12 million light-years away. (14.5-inch RC Optical Systems classical Cassegrain at f/8, SBIG STL-11000 CCD camera, Astrodon filters, LRGB image with exposures of 4.5, 3.5, 2.9, and 3.5 hours, respectively) /// **TONY AND DAPHNE HALLAS, FORESTHILL, CALIFORNIA**

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CELESTRON®

Astronomy's 2008 Guide to the Night Sky

LUNAR PHASES

New	First	Full	Last
Jan. 8	Jan. 15	Jan. 22	Jan. 30
Feb. 6	Feb. 13	Feb. 20	Feb. 28
March 7	March 14	March 21	March 29
April 5	April 12	April 20	April 28
May 5	May 11	May 19	May 27
June 3	June 10	June 18	June 26
July 2	July 10	July 18	July 25
Aug. 1	Aug. 8	Aug. 16	Aug. 23
Aug. 30	Sept. 7	Sept. 15	Sept. 22
Sept. 29	Oct. 7	Oct. 14	Oct. 21
Oct. 28	Nov. 5	Nov. 13	Nov. 19
Nov. 27	Dec. 5	Dec. 12	Dec. 19
Dec. 27			

All dates are for the Eastern time zone. A Full Moon rises at sunset and remains visible all night; a New Moon crosses the sky with the Sun and can't be seen.

THE MOON is Earth's nearest neighbor and the only celestial object humans have visited. Because of its changing position relative to the Sun and Earth, the Moon appears to go through phases, from a slender crescent to Full Moon and back. The best time to observe the Moon through a telescope comes a few days on either side of its two quarter phases. For the best detail, look along the terminator — the line separating the sunlit and dark parts. NASA

MARS shines big and bright early this year. As 2008 begins, it lies nearly overhead around midnight for Northern Hemisphere observers and stays visible all night. It also looks great through a telescope. Mars remains a fine sight through February's end. After that, surface details become harder to see as Mars' size dwindles. Viewed through a small scope, the planet's icy poles should stand out. Other features, such as dusky plateaus, are harder to see but should show up as contrasting shades of orange and brown. HST

JUPITER'S dynamic face shows an alternating series of dark belts and brighter zones pocked by the Great Red Spot. Even through a small telescope, the planet's four biggest moons — Io, Europa, Ganymede, and Callisto — appear conspicuous. You may see dramatic movement of these bright moons during the course of a single night. Jupiter reaches its peak in July, when it appears biggest and brightest, although it's a fine sight from February until early December. NASA/JPL/SSI

SATURN presents a dwindling view of its rings during 2008. The rings tilt a maximum of 10° to our line of sight in May. This tilt decreases steadily thereafter, reaching a barely perceptible 1° by year's end. Springtime offers the best chance to see the dark, broad Cassini Division that separates the outer A ring from the brighter B ring. The much thinner Encke Division lies near the outer edge of the A ring, and can be spotted on exceptionally good nights. HST

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WINTER

The sky

Winter boasts the brightest stars of any season. Orion the Hunter dominates the evening sky this time of year. Its seven brightest stars form a distinctive hourglass pattern. The bright blue star marking Orion's left foot is Rigel, and the ruddy gem at his right shoulder is Betelgeuse. The three stars of the Hunter's belt point down to Sirius, the brightest star in the night sky, and up to Aldebaran, the eye of Taurus the Bull. Above Orion lies the constellation Gemini the Twins.

Deep-sky highlights

The Pleiades (M45) is the brightest star cluster in the sky. It looks like a small dipper, but it is not the Little Dipper.
The Orion Nebula (M42), a region of active star formation, is one of the showpieces through telescopes of all sizes.
The Rosette Nebula (NGC 2237–9), located 10° east of Betelgeuse, presents an impressive cluster of stars and a gaseous nebula.
M35 in Gemini the Twins is a pretty open cluster best viewed with a telescope.
Castor in Gemini is easy to split into two components with a small telescope, but the system actually consists of six stars.

N
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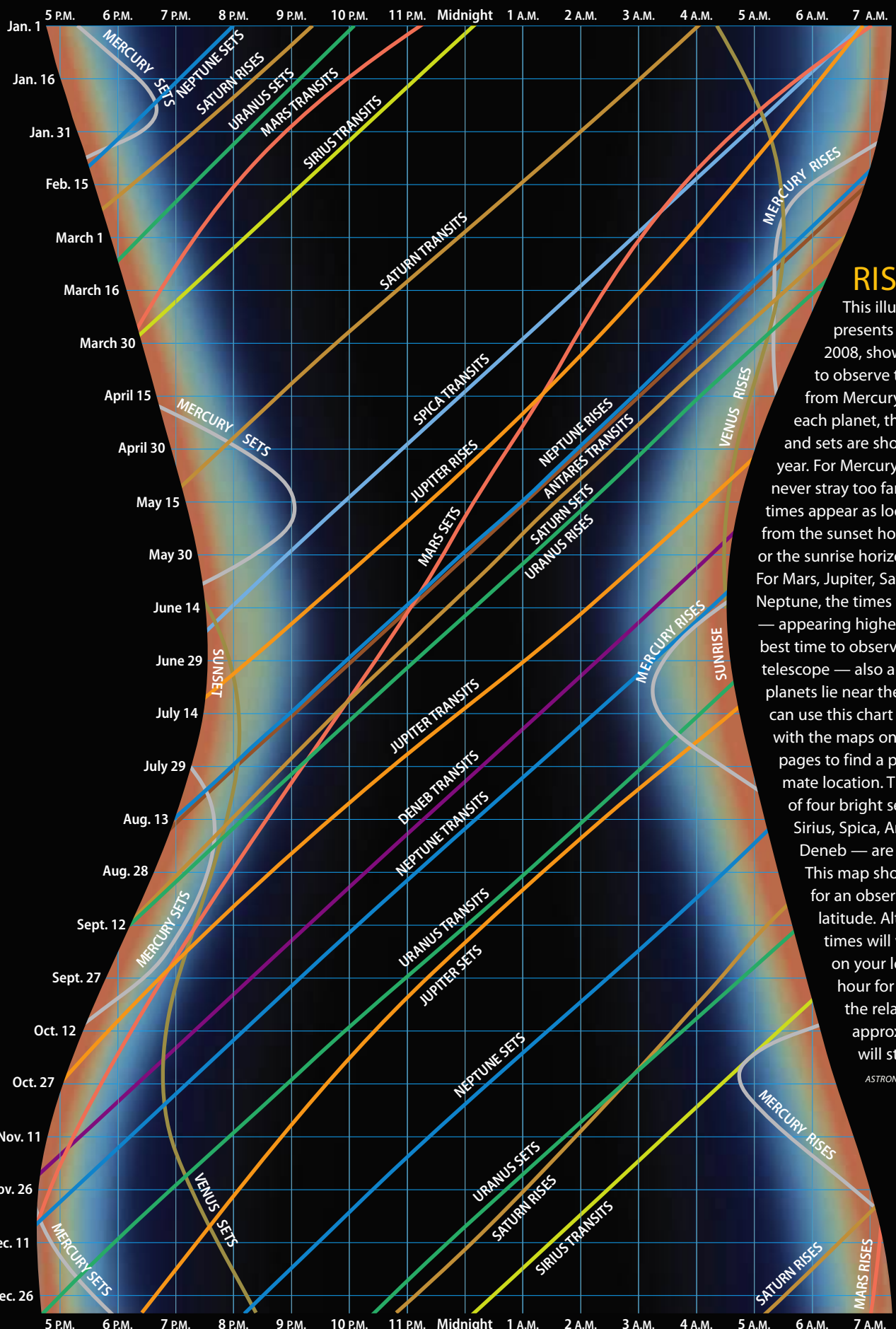
ECLIPTIC
Polaris
Mizar
Alcor
Dubhe
Merak
Phecda
Megrez
Alioth
Alkaid
Capella
Castor
Pollux
Pleiades
Aldebaran
Betelgeuse
Rigel
Sirius
Procyon
Regulus
Denebola
Spica
Arcturus
Vega
Deneb
Altair
Antares
Fomalhaut
Enif
Markab
Algenib
Alpheratz
Mirfak
Schedar
Caph
Navi
Ruchbah
Segin
Hamal
Sheratan
Mira
Diphda
Achernar
Acamar
Zaurak
Rigil Kentaurus
Hadar
Agena
Alphard
Miaplacidus
Suhail
Avior
Wezen
Adhara
Menkent
Gienah
Kochab
Zubenelgenubi
Zubeneschamali
Unukalhai
Rasalhague
Sabik
Kaus Australis
Nunki
Ascella
Shaula
Lesath
Saiph
Rigel Kentaurus
Peacock
Alnair
Atria
Alnilam
Alnitak
Mintaka
Bellatrix
Elnath
Menkar
Tarazed
Altair
Deneb Kaitos
Scheat



RISE & SET

This illustration graphically presents the night sky for 2008, showing the best times to observe the major planets, from Mercury to Neptune. For each planet, the times when it rises and sets are shown throughout the year. For Mercury and Venus, which never stray too far from the Sun, these times appear as loops coming up from the sunset horizon (on the left) or the sunrise horizon (on the right). For Mars, Jupiter, Saturn, Uranus, and Neptune, the times when they transit — appearing highest in the sky and the best time to observe them through a telescope — also are shown. All the planets lie near the ecliptic, so you can use this chart in conjunction with the maps on the previous pages to find a planet's approximate location. The transit times of four bright seasonal stars — Sirius, Spica, Antares, and Deneb — are included as well. This map shows local times for an observer at 40° north latitude. Although exact times will vary depending on your location (add 1 hour for daylight time), the relative times and approximate positions will stay the same.

ASTRONOMY: RICK JOHNSON